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Version: Version of Record

Link(s) to article on publisher's website:
<http://dx.doi.org/doi:10.21954/ou.ro.00007c94>

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Innovative Capabilities of the Agricultural Biotechnology Sector in Hungary

by

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A thesis submitted for the degree of
Doctor of Philosophy

Development Policy and Practice
The Open University

Date of Submission: September 2008

Date of award: February 2009

Abstract

This study investigates how context-specific institutional factors affect innovative capabilities of the agricultural crop biotechnology sector in Hungary. Answering this question has involved three areas of research, into: the network of actors and its accommodation of technological characteristics; the sustained use of institutional arrangements which characterised the pre-transition science and innovation system; and, the difficulty of adapting to the regulatory environment in the post accession phase.

The significance of this work results from the lack of current knowledge on the extent and survival of capabilities in this sector in Hungary. The study timing is also significant: This is a phase that demonstrates how the sector is surviving the economic crisis that accompanied transition and enduring the current political uncertainty surrounding national GM crop policy.

The study uses qualitative methods, comprising a series of in-depth investigations. Data collection via interview and observation began in 2006. Data collection and analysis were guided by a theoretical framework emanating from national innovation systems and triple-helix perspectives.

This thesis explores the challenges that are faced by an innovation system during economic transition. The thesis also contributes to the knowledge of science systems and how core science capabilities have contributed to the endurance of a sectoral innovation system. In conclusion the work finds that innovative capabilities in the Hungarian agri-biotech sector currently reside in the core competencies and activities of the science community in this sector and the networks they have created over time within and outside the country. Their future survival depends on the ability of the sector to adapt to the changing context. The institutions between actors and organisations are key to survival of capabilities and their ability to adapt. Institutions hold both the adaptive mechanisms for change and the legacies of the past which can help or hinder that change.

Acknowledgements

I would like to thank my supervisors, Professor Joanna Chataway and Professor Dave Wield whose confidence and encouragement allowed me to fully explore the field of study and inspired me to be creative in my writing. Their full support has meant more than this thesis, it has allowed me to grow in confidence as a researcher.

I would also like to thank my colleagues and friends in DPP. Their kindness and openness has given me many opportunities to publish, to read widely and to take part in the life of a department that over the course of four years, became my intellectual home.

This thesis is dedicated to my Mum and Dad. Without their support, encouragement and love, none of this would have been possible. Thank you.

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List of Acronyms

ABC	Agricultural Biotechnology Centre
CEE	Central and Eastern Europe
CEO	Chief Executive Officer
CMEA	Council for Mutual Economic Assistance
EEC	European Economic Community
EU	European Union
HAS	Hungarian Academy of Sciences
GDP	Gross Domestic Product
GM(O)	Genetically Modified (Organism)
IMF	International Monetary Fund
IT	Information Technology
MNC	Multi National Corporation
NGO	Non Governmental Organsation
NIS	National Innovation System
OECD	Organisation for Economic Cooperation and Development
PPI	Plant Protection Institute
R&D	Research and Development
SME	Small and Medium Enterprise
S&T	Science and Technology
STI	Science, Technology and Innovation
TEP	Techno Economic Paradigm
UN	United Nations
WTO	World Trade Organisation

Chapter 1: Introduction

1.1. Overview

1990 saw the end of communism in Hungary and the country's full engagement in a process of reform that would effect the entire economy. Transition towards a liberalised economy was accompanied by economic hardship and restructuring, and very often the contraction of many industrial sectors. This thesis investigates one particular sector, the crop agriculture biotechnology sector. Fifteen years on in May 2005 when work on this thesis began, Hungary had been a formal member of the European Union (EU) for exactly a year. The activities of this sector in Eastern Europe had begun to attract much attention as politicians, regulators, economists and non-governmental organisations began to consider the implications of Hungary's accession. The present research addresses one set of intriguing questions that emerge from this context; what were, and are now the scientific capabilities in the area of crop agricultural biotechnology?¹, did these capabilities survive the period of transition? And how well does the crop agricultural biotechnology science system adapt to the current and future position of Hungary in the EU? These points of inquiry are organised into the following research questions:

Main research question: How do context specific institutional factors effect innovative capabilities?

^{1 1} This refers to the selection of crop plant species with the use of molecular based techniques. Selection can occur through assisted conventional breeding techniques (where plants may be selected on a genetic basis, for example with molecular markers but not altered) or by genetic manipulation where the genome is deliberately altered for example with the use of a virus vector to insert a fragment of DNA. In the remainder of the thesis the term crop agricultural biotechnology may be shortened to agricultural biotechnology or 'agri-biotech', ignoring any implied inclusion of animal based agricultural biotechnology.

This question involves firstly an understanding of the context. The context refers to the inherited science and technology system created by the socialist legacy, the deterioration of that system during transition and the national and EU biotechnology regulatory framework that governs the innovation of GM crops in the country's post accession phase. Secondly the question requires an understanding of innovative capability in the Hungarian agricultural crop biotechnology sector and how those capabilities have changed, are changing and have the ability to adapt in the future. The context specific institutional factors are not themselves the subject of analysis, but the institutions which create innovative capability in this field. It is a study of the impact of one set of institutions upon another. The question is a complex one and is more easily answered by defining a series of sub-questions that aim to contribute to the whole;

Sub-question 1: Has the network of actors in the innovative agri-biotech sector evolved in a way that accommodates the particular characteristics of the technology?

Sub-question 2: Do linkages between actors in the network demonstrate the sustained use of institutional arrangements which characterised the pre-transition NIS?

Sub-question 3: Does this existing network as it has evolved, show difficulty in adapting to the regulatory environment created in the country's post accession phase?

In order to answer these questions a qualitative methodology was chosen. Qualitative methods of data collection and analysis, as explained in chapter 4, are well suited to the

investigations of institutions and the impact of the contextual factors on organisations and actors. Data collection methods used a mixture of secondary data collection, observation and semi-structured interviews undertaken in Hungary in autumn 2006 and Spring 2007. Interviewees included biotechnology scientists, students, policy makers and social science academics. Further details are given in chapter 4.

This work is important firstly because these questions have not been answered before. The most recent and comprehensive work undertaken in 1998 by Bross et al, did assess crop agricultural biotechnology capabilities in Hungary but was unable to take into account the unexpected turn of events with respect to national legislation on GM crops on the eve of accession. Here I refer to the ban on the commercialisation of all GM crops in the country. In addition to the destruction of academia-industry ties and the reduction in public funding this has created a new environment in which the system must adapt and survive. Adaptation of the system is further challenged by certain legacies of its Soviet past. Secondly this thesis adds to the understanding of science systems and innovation. In particular this work explains the role of the science system during transition in relation to the wider innovation system and how it retains innovative capabilities. And finally this thesis draws valuable lessons from the study of Hungary which are important to transition. These relate to the integration of the basic and applied sectors in science and innovation and the role and importance of policy.

The findings of the study point to various sources of innovative capability and adaptation by examining the ways that institutions in the biological science community operate. Key to maintaining innovative potential and capability, and adapting to a future that has a great

deal of uncertainty, are the networks between individuals and organisations and diversification of activities.

1.2. The Structure of the Thesis

Chapter 2 provides the background information for the thesis relevant in answering all three sub research questions. This chapter contains a description of the science system in Hungary from its development during and after communism and the context in which it has evolved. But in addition to providing the background information and context, the chapter introduces the idea that history matters. The actors and the scientific culture that they perpetuate are influenced by events and the structures that were created in the country's Soviet history. Chapter 2 also reviews the two most recent pieces of literature that have similarly attempted to sketch out the Hungary's biotechnology capability. In reviewing these works it is possible to identify the gaps in the literature which this study can fill and in doing so make a valuable contribution to the body of existing knowledge. One obvious contribution is the contemporary nature of this thesis and the inclusion of the recent accession events that have prompted the unexpected changes in government policy. This is briefly discussed in the last part of chapter 2.

Chapter 3 takes forward the idea of an inherited system of science and technology and the need to adapt and change by posing a theoretical framework. The chapter focuses in particular on the National Innovation Systems literature and the Triple Helix concept in order to theorise how the innovative potential of a particular sector may be challenged by the contextual factors detailed in chapter 2. These areas of interest are focused into the main

research question and the three sub research questions. By posing a research question, the thesis concentrates its focus and is able to prioritise the layers of investigation which emerge as “the study of one set of institutions upon another”. By partially operationalising and defining concepts such as ‘institution’ and ‘innovative potential’ the chapter not only provides the theoretical basis for analysis of data, but also provides an entry point for the data collection strategy.

Chapter 4 of the thesis explains the strategy behind data collection and analysis. The chapter reasons that operationalisation of the main concepts in the manner described in chapter 3, requires a qualitative approach to data gathering. At this point it is also argued that this study which takes into account various differentiated actors and multiple institutional layers, does not fit neatly into a case study approach and so is better described as an in-depth investigation of a system. There still exists the problem of generalisability and this problem is discussed in some detail here. The final part of chapter 4 looks at the method of analysis, the ethical considerations given throughout the course of the study and problems in data collection.

Chapter 5 is the first of three data chapters that presents and analyses the data collected. The aim of this chapter is to detail the actors, organisations, innovative activities and linkages of the agri-biotech sector and to outline the parameters of the investigation. This fairly comprehensive picture of the agricultural biotech sector highlights certain rudimentary problems. In particular there is a reinforced distinction between basic and applied research. There are also definite ‘holes’ in the innovation system that policy has attempted to address, but has not been able to solve at the level of the sector. The private

sector is comparatively small and there is a lack of connection between industry and academia. These problems indicate that certain legacies of central planning are proving difficult to shake off.

Chapter 6 delves further into the problem of how a system operates in the context of a challenging environment. There are particular political, economic and market uncertainties which prevent innovative actors in the agricultural biotechnology sector from pursuing certain paths or trajectories. The question that is asked is whether these actors are able to sustain themselves and preserve innovative potential in this uncertain environment. The answer that emerges is that actors are able to engage in coping strategies which involve divergence of activities. Some of these strategies mark a long term shift in trajectory and capabilities whereas others promote the tradition of basic or fundamental science that was typified during Soviet times.

Chapter 7 takes one particular coping strategy to study in some depth as it became strongly evident in the data collected. That is the formation of networks and collaborations in response to reduced funding and the regulatory ban on GM commercialisation. Both national and international collaborative efforts become examples of how learning in scientific communities persists, how lack of national demand for biotechnology can be circumvented and how amidst the economic difficulty and reduced national funding, the Hungarian scientific community might prosper in the longer term.

Chapter 8 concludes the thesis. The chapter first pulls together from previous chapters the data and analysis that answers the three sub-questions and the main research question. This

is followed by the policy implications and lessons that can be drawn from this study. Section 8.4. outlines the main limitations of the study which include the lack of certain perspectives and the problem of generalisability.

8.5. reviews the original contribution of the thesis which may be summarised as; the investigation of innovation from a different and particular angle, the exploration of the science system in relation to a wider innovation system and lessons from Hungary that are relevant to transition. The chapter ends with a brief discussion on how the research may be taken forward.

Chapter 2: Biological Science Development in Hungary

2.1. Introduction

The aim of this chapter is to provide the reader with an understanding of the history of the science and technology system in Hungary. “History does matter”(Havas 2002, p381), and before discussing in the proceeding theoretical chapter why that might be the case, it is important to give a description of that history here. By describing some crucial factors that have contributed to the development of biological sciences in Hungary, this chapter will also develop the proposition offered in chapter 1, that agriculture biotechnology innovation must be studied as a system in context. Because this is a study of a single sector, it is not the aim of this chapter to provide a comprehensive description of the country’s history, but only those relevant historical factors. These factors contribute to background information directly relevant to all three sub research questions; in describing the relative independence of Hungarian scientific networks compared with other Eastern European countries (contributing to sub-question 1), the pre-transition institutional arrangements (relevant to sub-question 2), and the regulatory framework (featured in sub-question 3).

What follows is a description of the science system generally in Hungary from its development during and after communism and the context in which it evolved. This chapter will form the historical basis of later chapters which refer to various actors, events and the scientific culture in Hungary which proves to be influential in today’s existing agri-biotech innovation system. Two pieces of literature are reviewed in order to demonstrate the type of survey work that has been carried out by other authors. The literature presented here does

not add to theoretical development, which is the focus of the next chapter, its purpose here is to add to the background and context information by describing the current science and technology system. Chapter 1 explained why a study of the biotechnology innovation system in particular would be illuminating. Briefly this chapter also sets the context of the GM crop debate, the current situation in Europe and Hungary. Chapter 3 brings together the relevant theoretical literature on innovation systems whilst reflecting on the realities as described in this chapter concluding with how and why particular theories provide insight in the Hungarian context.

2.2. Science and Technology Before and During Communism

Following the collapse of the Austro-Hungarian monarchy during the First World War, The Communist Party of Hungary, led by Béla Kun, came to power in 1919. The communist government led by Kun embarked on an extensive program of nationalisation. Popular support for the communist government was short lived. After an attempted coup, the government undertook a series of actions called the 'red terror', murdering hundreds of people. A counter-revolutionary army led by István Bethlen, a Transylvanian aristocrat, and Miklós Horthy, the former commander in chief of the Austro-Hungarian Navy, executed many communists and was named the 'white terror'. In November, 1919 Horthy's army marched into Budapest and that government gradually restored security and set up authorities. However, Kun supporters were imprisoned and radical movements were still suppressed. The peace Treaty of Trianon signed in June 1920, after defeat in World War 1, required Hungary to surrender over two thirds of its territory to Romania, Czechoslovakia, and the Kingdom of Serbs, Croats and Slovenes. Prime ministers subsequently appointed

by Horthy amended electoral law, provided jobs in the expanding bureaucracy to his supporters, and manipulated elections in rural areas, but restored order to the country by giving the radical counterrevolutionaries payoffs and government jobs in exchange for ceasing their campaign of terror against Jews and leftists. Hungary suffered in the Great depression in 1929 and a treaty was signed with Germany that assisted in the Hungary's recovery from the depression, though made the country dependent on the German market for raw materials. Hitler used economic pressure and the promise of returning lost land to coerce support for Nazi policies. Hungary joined the German effort and went to war against the Soviet Union in 1941. Suffering heavy losses, Hungary sought surrender, at which point Germany troops occupied the country. Horthy was replaced by a puppet government loyal to Germany until 1944.

The Soviet invasion occurred in 1944 after the fall of Nazi Germany and lasted until 1945. 1948 marked the establishment of Stalinist rule by communist leader Mátyás Rákosi, complete with planned economy and forced collectivisation. The 1956 Hungarian Revolution against the Stalinist government and its Soviet policies started as a student demonstration against the communist government in Budapest but quickly spread throughout the country. There was a brief period of liberalised political activity lasting less than a month before the Soviet Politburo intervened² and made the decision to quash the revolution sending in Soviet forces and killing thousands of civilians. In 1989 the Soviet Union decided to reduce its involvement and agreed to withdraw Soviet forces by June 1991.

Political Bureau of the Central Committee of the Communist Party of the Soviet Union²

Central planning controlled nearly every aspect of the economy including the education system, research, innovation and product development. We begin with the cornerstone of basic science research; the Academies of Sciences. Balazs (1997), describes the Academy 'model' as being developed in Russia and then rolled out to all the countries of the Soviet bloc. The Soviet academy model suffered the same problems as most large bureaucratic organisations and other European academies. However, it is not simply a variant of the European model. In its conception of science, technology and innovation, as well as the wider system within which it operated, it is something quite unique. The Hungarian Academy of Science (HAS) was established in 1927 but was reorganised and absorbed into the Soviet model. However, the ideology of 'scientific socialism' gave priority and respect to science and so the old generation of 'bourgeois' scientists were allowed to keep their jobs. The HAS was thus able to maintain some degree of independence. Soviet politics influenced the organisation of the academy by the focus on particular scientific fields. The natural and technical sciences, particularly those associated with military capability became dominant in most academies (ibid). Hungarian academicians became renowned for their ability in mathematics and physics. The Manhattan project (the building of the first hydrogen bomb) was often mentioned during interviews, recounting the story of Hungarian physicists such as Edward Teller, Leo Szilard and Eugene Wigner who fled to the US during the Stalinist era and significantly contributed to the development and progress of nuclear weapons technology in the US.

Other features of the Hungarian academy in common with the Soviet academy model include its management, organisation and financing. The network was divided by discipline as described above, but also linearly through departments and research groups. This

reflected the linear model of technology development that was the basis for research under central planning. The academy had a president elected by a general assembly. Members of academy were elected by the existing academicians. In the beginning the main criteria for election was individual work and progress, later membership was increasingly influenced by political loyalties. The institutes of the academy received basic funding from the central budget and this was dependent on the number of employees. And so the only incentive was to grow since an increased size meant more funding (Balazs 1997). Various studies in the 1970s report that rapid expansion throughout the USSR since 1928 resulted in a Soviet R&D sector comparable in size to the US. Progress was seen to be remarkable; 7600 innovations by 55 large firms in Poland during the period 1973 – 1978. However, if it is realised that 20% of these were failures, 80-90% were small innovations and minor in-house improvements with only 2% being classified as major structural innovations (Gomulka 1986), it becomes apparent that the figures are much less impressive.

Despite the enforcement of the Soviet model principles, the science systems, culture and the academies, showed variation across the CEE bloc. Balazs (1997) argues that no two countries in the bloc were more dissimilar than Russia and Hungary, Hungary being much smaller with less of a military industry and being the most advanced in terms of market experience. One role played by Hungarian research institutions was to channel western technology to the Eastern European market. They imitated, copied and reinvented western products such as computer production. Biology was a relatively neglected scientific discipline across the Soviet bloc not only because other disciplines were more closely related to military efforts but also because biological science programmes were more

expensive to run in terms of equipment (Senker 2007). While this was true also in Hungary there was nevertheless a difference in scientific culture.

T.R. Lysenko was director of Soviet biology firstly under Stalin in 1927 and then later under Khrushchev. Lysenko rejected Mendelian genetics in favour of the hybridisation theories of another Russian horticulturalist, Ivan Vladimirovich Michurin. Backed by unorthodox experimental and fraudulent research he gained favour with Stalin, won all manner of prizes and was promoted as an example of how practical solutions may triumph over theoretical research. His ideas gained momentum and created its own political movement 'Lysenkoism', promoted by the Soviet propaganda machine. After the famine and loss of yields that followed forced collectivisation his promises of increased yields through his own brand of agricultural techniques were generally welcomed. It was also communist party policy to rapidly promote members of the proletariat into leadership positions. Born to a peasant family, Lysenko fitted the bill. When the discovery of the double helix was being talked about with great excitement in the west in 1961, it was nearly impossible to publish anything regarding this in the USSR. Lysenko was finally dismissed in 1964 and was blamed for setting Soviet progress in biology back by years and perhaps by decades. Hungarian academics in the field of biology, on the other hand did not become engaged in Lysenko's movement. Credit for this is given to those such as Albert Szent Gyorgyi, a forward thinking and politically influential Hungarian biologist. Between 1928 and 1933 Szent Gyorgyi led the team that discovered vitamin C. He was awarded the Nobel Prize for medicine in 1937. Hungary continued to build on a tradition of pharmaceuticals and during the communist era, provided the COMECON area (CMEA region) with two thirds of its pharmaceuticals (Rafols, 2006).

Consideration of these events are important for two reasons. Firstly, the Lysenko movement via its progress in the wider Soviet Union but its marginal impact on the Hungarian science system, is likely to mean a difference in culture amongst the scientific communities. It may be expected for example, that scientists in Hungary are more open to new technologies and knowledge in the field of biology, they may be better linked to the international scientific community etc. Secondly, since progress in Hungary was not hindered in the same way as in the rest of the Soviet Union, Hungary may have a relatively more advanced level of expertise in the area of molecular biology. Since molecular biology may be considered a 'ladder technology' (Inzelt, 2004), meaning a "universal enabling technology which can be used within different industrial sectors at different innovation stages" (Bross et al, 1998, p.3). it is all the more important and is a founding base for various industrial applications and emerging scientific areas, for example application in plant and animal agriculture, drug and vaccine development, veterinary science, diagnostics, synthetic biology, etc.

Generally under the Soviet regime, all researchers were employed by the academies or government research institutes. Universities became mere 'teaching factories' undertaking no research. Here again Hungary (and also in this case, Poland) show some differentiation with some research being undertaken at universities (Radosevic and Auriol, 1999).

Partial reform began in Hungary as early as the 1960s. Initial political changes in the early 60s led to the establishment of the New Economic Mechanism in 1968, abolishing strict central planning and introducing market stimuli. 'Self-accountancy' replaced planning at

the firm level and profit making became meaningful for management. In 1969 new science policy guidelines were announced which called for the prioritisation of practical results and stressed the economic impact of science. The Academy was also reorganised with its scientific community being divided from its management. The secretary general was appointed by the government to be head of the 'academy office' and his role was to be like that of a minister.

The 1960s in Hungary marked a period of slow-down in economic growth, and with this came reductions in R&D expenditure and a freeze in funding for the academy. The reforms of the late 60's did however allow for contacts to be made with industry and state organisations and so there was an opportunity for additional sources of funding. However, it was the financial pressure and economic environment of the shortage economy that transformed many of the research institutes. They formed industrial contracts which tended towards maintenance, technical upgrading or solutions to bottleneck problems rather than implementation of new technologies as such (Balazs, 1997).

Applied research and product development was undertaken by government industrial research institutes. Catalogues of 'innovations' were churned out year after year by such institutes, these were forwarded to industry and government factories where managers would then choose which to use or implement (Interview, 2005)³. Innovation in industry stagnated. Radical innovation requires not only a change in thinking and practice but can also depend on an initial large investment, neither of these were abundant under the Soviet system where profit was not available as facilitator or motive. Factory managers were

³ Interview with Virginia Acha in 2005 undertaken as part of an MSc study by the author

rewarded for cost reductions and increases in efficiency which were most easily achieved by improvements in the short run. With the focus on these immediate goals, long run improvements that usually require innovation, investment and can result in a temporary slowing, were not considered.

The system as a whole across CEE was primarily financially but also restricted in other respects. The academy and the universities competed for the same budget. Academics were not allowed to travel outside the country, though in Hungary the situation was more relaxed (various interviews, 2006). Other features commonly discussed by academics include the non existence of capital markets, one-off technology imports that resemble import substitution regimes, an R&D sector that was separated from production and market structures which have a high degree of vertical integration and weak subcontracting networks (Radošević, 1997).

2.3. The Innovation System During and After Transition

Transition is understood here as an institutional transformation towards a market economy. There are two main methods of transition; ‘big bang’ or ‘shock therapy’ and ‘gradualism’. The measures which constitute shock therapy are firstly liberalisation to include the freeing of prices, foreign trade and the end of central planning, secondly a program of privatisation of state enterprises and thirdly measures to promote macro economic stabilisation. Bringing about economic stabilisation was usually done through the employment of severe austerity measures particularly in order to repress inflation (Jeffries, 2002).

Inflation was a common outcome in many transition economies for various possible reasons. It is likely that ending central planning and government production of goods left a gap in the market. Though this should theoretically have been filled with the creation of private enterprise, there may be expected a long delay in the establishment of private production systems and functioning markets where these did not exist before. For the private sector to establish itself it is necessary to have entrepreneurs, financial and physical infrastructure and supporting businesses such as accountancy and law services.

In fact it is this theoretical inelasticity of supply that is the major criticism of shock therapy agued by academics in favour of gradualism. Other critics suggest that the cost of making a mistake in the shock therapy process is likely to be large whereas with a more gradual approach small errors may be contained and corrective action can be built into the reform process. It is also argued that the shock therapy strategy puts severe strain on society and reforms may become associated with hardship. A subdivision of gradualism is the 'evolutionary school'. Authors from this perspective claim that shock therapy does not consider current institutional structures with due regard to their history, that shock therapy seeks to side-step existing institutions or replace them entirely rather than examining them in order to see how to change them. A gradual phasing out is preferred and in doing so, an understanding of capitalism is gained and the factors that produce growth and change such as innovation. Evolutionists place greater emphasis on an approach that stresses the rigidities in organisational behavior and the importance of entry and exit process. They therefore are in favour of policies that prioritise the growth of new private firms over privatisation (Jeffries, 2002).

Advocates of shock therapy argue that rapid change provides unambiguous signals of intent in the direction of reform and the bypassing of bureaucracy with rapid reductions in state regulation helping to deter corruption. They also suggest that following a change in government, leaders are able to use a 'honeymoon period' shortly after election to make irreversible, comprehensive and often painful measures towards a permanent reform (Jeffries, 2002).

Hungary had a more gradual approach to many other countries of the Soviet bloc. As mentioned above, initial reforms took place in the 1960s. The country then underwent a significant program of more intensive reforms in the early 90s when Soviet rule ended. Austerity measures in line with IMF guidelines were introduced in 1995 and included expenditure cuts, limits in public sector wage increases, a devaluation of the forint against the dollar, and an increase in import duties (except on machinery, equipment, energy and components for exports) (Jeffries 2002). GDP reached a low of -11.9 in 1991 and gradually improved, becoming positive in 1994 and increasing to 4.5 in 1999. Since 1997 GDP has grown at an approximate rate of 4% a year (Rafols, 2006). The inflation rate was at its highest in 1991 when it reached 35% but similarly improved, declining steadily until the end of the 90's (EBRD, 2000).

Economic history effected development of the agri-biotech innovation system in various ways. First it explains the conditions under which the breakdown and rebuilding occurred. Amidst the economic crisis as described above, science and development was not at the top of policy makers agendas (Chataway 1999). It has been argued that in an attempt to reverse the extremely interventionalist role of the state during the socialist regime, the draw back of

the state from many policy area's has resulted in a transitional period where the state did not intervene enough (Von Tunzelman, 2005). This raises questions about the development of science in absence of policy and a regulatory framework.

Secondly the extent of adjustment and rebuilding might be assessed. With the breakdown of the CMEA market, industrial production shrank, as did industrial R&D and state expenditure on it (Chataway, 1999). Old links between the research sector and industry disappeared (Interview with Hungarian scientist, 2006) and emigration is leading to significant losses of qualified personnel (various interviews 2006). The research institutes themselves had been previously suffering from problems of inefficiency, excessive size, fragmentation and failure to recognise that change was occurring. These problems according to Balasz (1997), were exacerbated by transition. In the face of economic change, the Hungarian and Russian academies opted for a defensive approach rather than searching for a way to adjust.

Thirdly, the economic background will indicate the nature of change and the likely differences between CEE states. Technological capability has come to be seen as residing in complex networks of actors (Porter 1990, cited by Chataway 1999). I assume that the rate at which industry shrinks, crisis occurs and ties are lost will effect the character of the new S&T system as it emerges. A gradualist approach to transition, such as that taken by Hungary may have prevented a more sudden shrinkage of industry and the economy, perhaps allowing old links between the actors of the research system to survive or adapt instead of disappearing. This assumption has one notable implication, the maintenance of 'institutions' and 'rigidities'. Both these concepts will be discussed in chapter 3.

Amongst the first studies undertaken with respect to biotechnology in CEE specifically, was that carried out by Tzotzos and Skyrabin in 2000. These authors compiled a list of many of the organisations responsible for development in plant biotechnology across CEE at the time. Their study shows a considerable amount of activity particularly in Hungary, Poland and the Russian Federation. There have been two other detailed and recent studies which greatly contribute to knowledge on this area.

Firstly, The Biotechnology Audit (Bross, et al. 1998) which collected data in the period 1995 - 1996, aimed to assess the strengths and weakness of the Hungarian biotechnology sector in order to support science and technology policy design. It also aimed to identify future areas of competitiveness not only by assessing technological standards and human resources, but also the interaction between the different actors of the innovation system. The authors cite the importance of biotechnology to Hungary as a “universal enabling technology which can be used within different industrial sectors at different innovation stages” (Bross et al, 1998, p.3). It is also considered “a basic technological precondition for the further interdisciplinary development of other critical technologies.” The main data collection method consisted of interviews with firms and institutes and their documentation. Interviews contained open and closed ended qualitative questions and were conducted in English. The audit used in addition specific economic and technical indicators developed with consideration of the transition context. Hungary was then compared to similar analyses performed on the US, Germany, Japan, the UK and Israel. The audit made the following conclusions:

The privatisation process had not been completed in the time frame studied, but needed to be. The legal and regulatory system also needed to be improved and clarified. Concerning the future of biotechnology firms, it was found that lack of public funding was still a major issue. The two main governing bodies for allocation of these funds (the OMFB⁴ and OTKA⁵) do not give clear priorities for allocating these funds. Research carried out by industry is very limited. Industry still has an expectation that it is the role of the government to provide them with research and R&D outputs, which they are waiting to commercialise. According Bross et al, business has yet to learn that R&D results require investment.

Bross et al conclude by saying that the Hungarian biotechnology sector has maintained a good quality of human resources though there are not enough well educated specialists. They suggest that government and industry have to create more possibilities for the education and training of young specialists for example by the provision of post graduate courses.

A 'specific' biotechnology law has not yet been enacted (Bross et al, 1998). So there is a missing biotechnology framework which leads to an uncertain situation and planning security issue for firms. The approval procedures for pharmaceuticals and foods are slow and costly.

⁴ (National Committee for Technological Development. Translation from the Hungarian: Oeszagos Muszaki Fejlesztési Bizottsag.)

⁵ National Scientific Research Fund. Translated from the Hungarian: Orszagos Tudomanyos Kutatasi Alaprogramok.

There has not been as yet a public debate about biotechnology. Nor are there any lobbies against biotechnology. This is described by the report as an opportunity and strength. The authors state that “the country can avoid the emergence of a negative public attitude towards biotechnology if public knowledge is increased in time so that the public can decide on a well-informed basis about accepting biotechnology products” (Bross et al 1998). However, public knowledge does not necessarily influence biotechnology acceptability (Sturgis et al, forthcoming) and also there has not been enough time to create a well informed public. There is still a lack of public debate (interview with Hronsky, 2006) and there is an emergence of general negativity and public mistrust around the issue of biotechnology (Gyula, forthcoming) .

There was at the time of this study, no apparent demand for biotechnology products or processes. The relationship between science and industry was weak, as were cooperative efforts with industry. The audit judged that firms must invest more in marketing and developing links with other actors. A new style of management is also required in R&D organisations in order to survive in a new political environment and a competitive global market.

The report describes the sample for agriculture as being strong and able to survive the turbulent changes in ownership, organisation and management. On the other hand large Hungarian pharmaceutical companies have had very limited success in biotechnology commercialisation and most firms are leaving the sector. The final conclusion of the report is that Hungary can expect a good position in food biotechnology with other biotechnology sectors looking less promising.

These conclusions of course were made before accession and the regulatory changes that followed. The present situation I would judge now to be somewhat the reverse of that written above and the regulatory background to this is given in the final section of this chapter.

Secondly, Rafols (2006)⁶ in a quantitative study, investigated policies and programs relevant to the Hungarian biotechnology sector from 2002 - 2005. Rafols credits Hungary with the largest biotechnology sector in CEE with an estimate of approximately 100 biotech firms. 30 of these are counted as being ‘intensely biotech focused’. These firms generate €50 million in sales and 800 – 1000 core biotech jobs. Figures from 2005 show that biotechnology employs 2.6% of the industrial workforce and estimates in 2002 give biotech R&D activities amounting to €100 million. Hungarian biotech firms are providing services and tools that are used by international firms. There are some transnational corporations present in Hungary, mostly in the area of pharmaceuticals and only 2 in agro-food. The lack of university-industry collaboration is outlined as being an important perceived obstacle. Other interesting features in the report include the centralisation not only of biotech R&D (69% of expenditure in Budapest) but also of policy making. Very little relevant policy is created or managed at a regional level.

Prior to 1990, the OMFB was a prominent ministry, designing and managing science and technology policy. It lost status in the 1990’s and became a division of the ministry of

⁶ This national report titled “Inventory and Analysis of National Public Policies That Stimulate Research in the Life-Sciences and Biotechnology, its Exploitation and Commercialisation by Industry in Europe” written by Ismael Rafols is a soon to be published as a contributory chapter to the BioPolis Framework Program 6 Project undertaken by SPRU at the University of Sussex in July 2006.

Education in 2000 which then took the lead on policy in this area from 2000 to 2003. The 1999 Szechenyi plan was designed to strengthen R&D through the establishment of various programs carried out by the Ministry of education. These included a National Scientific Research Fund (OTKA), a National R&D Program to fund applied research (NKFP), and a National Technological Development Program to fund technological development (KMUFA).

2003 however was a year of major reform for S&T policy in Hungary giving rise to most of the bodies which comprise the current governance system. These include:

- The Science and Technology Policy Council (TTPK⁷), chaired by the prime minister, vice chairs are the Minister of Economy and Transport and the Minister of Education and attended by the president of the HAS. The Science and Technology Advisory Committee (TTTT) is an advisory body of the TTPK.

- The Research and Technology Innovation Fund. This replaced and used the funds from the NKFP and KMUFA, and added to this an innovation tax on revenue levied on medium and large firms at a rate of 0.3% in 2006 and for small firms 0.2% from 2007 onwards. Decisions on fund allocation are taken by the Research and Technological Innovation Council (KTIT⁸), a body of 15 members representing government ministries, industry and the research community.

⁷ Translated from the Hungarian: Tudomány és Technológiapolitikai Kollegium.

⁸ Translated from the Hungarian: Kutatási és Technológiai Innovációs Tanács.

-The National Office of Research and Technology (NKTH⁹) is the governmental organisation responsible for the design, implementation and evaluation of S&T policy and programs. It also coordinates international cooperation and EU integration of STI.

The NKTH oversees The Agency for Research Fund Management and Research Exploitation, whose job it is to implement innovation policy and manage the Research and Technology Innovation Fund (mentioned above).

- OTKA still exists as the fund given by the government to support basic research. It is managed by its own committee.

- The HAS is still financed by the state and is accountable to the Hungarian Parliament. Rafols reports its share of total research activity to be about 10%, though in the natural sciences conducting around half of Hungary's R&D.

(See Appendix A on Hungary's structure of governance and funding)

Hungary has used a number of generic and biotech specific policy instruments summarised by Rafols using table 1:

⁹ Translated from the Hungarian: Nemzeti Kutatási és Technológiai Hivatal.

Table 1: National public policy-directed biotech stimulating instruments in 2002 – 05

Instrument	Funding Organisation	Budget (millions of Forints)	Budget (millions of Euros)	% of Total
Generic				
National R&D	NKTH	11,446	45.8	55.1%
Applied R&D	NKTH	4,907	19.6	23.6%
Hunagry Enterprise Promotion	Ministry of Economy	296	1.2	1.4%
Subtotal Generic		16,649	66.6	80.1%
Biotech Specific				
Biotechnology 2000	Ministry of Education	1,500	6.0	7.2%
Innovation Clusters	NKTH	1,625	6.5	7.8%
Bioincubators	NKTH	1,000	4.0	4.8%
Subtotal Specific		4,125	16.5	19.9%
Total		20,774	83.1	100%

Adapted from Rafols, (2006)

Before concluding this section, a brief note on the instruments indicated above:

The national research and development program (NKFP) was launched in 2000 and contains six thematic areas, one of which is “Life sciences, Agri-food industry and Biotechnology”. The aim of the NKFP is to promote long term economic development which it does through the funding of projects that are carried out by consortia comprising research organisations, NGOs and industry. Industry led consortia are given priority in the

selection. A maximum of 250 million Forints (1 million Euros) can be allocated over one year for a project or 850 million Forints for a three year project. In 2005 it was expected that between 30 and 50 projects would be funded. The total fund for 2005 was 18.5 million Euros. On average half the funding is allocated to health biotechnology projects and the balance between basic and applied research is 30% and 70% respectively.

The applied R&D program belonging to the NKTH aims to foster collaboration between industry and academia. Open calls took place in 2004 with biotechnology being granted 4,905 million Forints (One third of the total). Funding is for 3 year projects.

The Hungarian Enterprise Promotion agency promotes the licensing and commercialisation of Hungarian innovations abroad. It had a budget of 592 million Forints over the period 2002-05, of which approximately half was allocated to biotechnology.

The Innovation Cluster (Asboth Oszkar) Program aims to set up clusters and technology platforms in the health, biotechnology and agriculture based renewable energy industries. The funding can be for a maximum of 4 years, and there is a total budget of 6,500 million Forints (26 million Euros) over 4 years.

Biotechnology 2000 was produced on the basis of a national study in 1999. It lasted until 2002. It is the largest biotech specific initiative in the time period under review in the study, costing 4,500 million Forints. It has the goal of enhancing the knowledge base for biotech R&D with the following priority areas; food safety, phytotechnology, bioconversion,

bioremediation, the application of biotech to environmental issues, biotech in animal breeding, biomedicine, biopharmacology, and bioinformatics.

And finally the bioincubator program. This is also distributed on the basis of a competitive call. The fund was created to provide incubators for SMEs working in biotechnology. The initial call was open over a two year period with a commitment to assist in entrepreneurship and innovation activities for at least five years.

Rafols work provides some indication of the quantity of government investment and range of activities over the years 2002-05. However it must be considered that biotechnology as a sector covers animal biotech, medical and human biotech, pharmaceuticals and plant biotech. In light of the recent moratorium and the trend away from the plant sciences (interview data), plant biotechnology is likely to be a small proportion of these and other such amalgamated figures. Figures for plant biotechnology sector alone do not exist and any qualitative indicators that do exist do not reflect innovation and the knowledge production that contributes to innovative capability. A part solution to this problem would be to perform a statistical summary of the literature and articles produced by Hungarian plant biotechnologists and scientists. This poses problems such as the requirement to survey journals produced in the Hungarian language and counting not only single authored papers but those produced jointly by Hungarians and those working in multinational teams. These problems are solvable but a bigger problem exists in that while knowledge is a significant component of innovative capability, I do not wish, at the outset of this grounded piece of work, to define innovative capability solely in these terms. See section 4.4. for further details.

2.4. EU Accession and the Challenges

The regulation of GM crops began in the 1980s, developing simultaneously in the European Union and the US. The European approach to agri-biotech policy making has a distinctive characteristic in that it demonstrates a risk governance approach. Whereas in the US, GM technology was framed as not being significantly different to conventional crops, in the EU it was framed as a radical departure from convention and as a product with unpredictable properties. The US therefore used an existing regulatory approach but the EU, emphasising the novelty of the process of genetic engineering, created a process rather than product based regulatory system (Tait, 2007). Concerns exist over cross pollination of genetically modified crops with conventional crops or weedy relatives, ‘contamination’ of organic food sources, disruption of the ecosystem through adverse effects higher up the food chain, foreign gene products creating allergens and inadequate testing and labeling capabilities. Laboratory based experiments that have so far offered evidence showing GM crops as harmful¹⁰ are disputed. Neither side is able to claim an irrefutable scientific standpoint.

The first European Commission directive, was developed after a long consultation process. It was however replaced by a temporary moratorium on GM crops from June 1999 onwards (Levidow et al, 2005). After re-assessment of the regulatory system, this was in turn replaced by a more restrictive legislation, the Deliberate Release Directive 2001/18/EC (Tait, 2007). Other regulations which are relevant to the innovation and commercialisation of GM crops are Directive 90/219/EC which regulates the contained use of genetically

¹⁰ such as the study on the Monarch butterfly by Losey et al in 1999 and the digestive systems of rats by Pusztai also in 1999, fuels much of the debate

modified micro-organisms, Regulation (EC) 1829/2003 on genetically modified food and feed and Regulation (EC) No 1946/2003 on transboundary movements of genetically modified organisms between member states¹¹.

Hungary joined the EU in 2004. Aligning with the large body of legislation that is the *Acquis Communautaire* in accordance with the Copenhagen criteria, was judged to be a complicated task requiring significant institutional capacity. With particular respect to biotechnology, new accession countries had to consider the approach adopted by the EU which has demonstrated a shift from 'government' to 'governance'. Yoder (2003) notes not only this but a shift in emphasis towards multi-level governance and an importance being allocated to sub-national units of authority. The challenges involved decentralisation, creating arenas, institutional capacity and engaging multiple stakeholders.

It was a widely held belief that CEE countries will become passively compliant with EU regulatory and governance requirements and their national perspectives will become eclipsed by EU hegemony. It was argued that small states with small administrations have insufficient capacity to address all negotiations owing to lack of staff, expertise and other resources thus leading to this pattern of integration behaviour (Jehlicka and Tickle, 2004). Of significant concern was the theorised 'race to the bottom', in other words the competitive adoption of the lowest possible standards in terms of biosafety and regulation. In the case of biotechnology in Hungary, neither of these fears fully materialized. Hungary adopted particularly stringent national legislative forms of the *Acquis Communautaire* relating to agricultural crop biotechnology, seeing for itself a niche in the organic European

¹¹ Europa: http://ec.europa.eu/food/food/biotechnology/index_en.htm

market (interview data, 2006). Negotiation with the European Commission over national laws on co-existence of genetically modified crops and the de-facto moratorium banning all commercialisation (including those already approved by the EU) is still ongoing.

There is activity in areas which might be termed pre-commercialisation or development. For example Hungarian law does not prohibit field testing of GMOs, with the exception of two Monsanto varieties (Interview data 2006). Between 2005 and 2007 Hungary had field trials for 26 GM varieties, but none in 2004. This compares well to other EU members. For the same period, the UK for example field tested 4 varieties though in the period 1993 – 2007, it was much more active, testing in total, 234. Germany tested 25 varieties between 2005 and 2007, though in previous years, likewise its activity had been much higher. France and Belgium show very similar patterns. It seems that at a time when activity has subsided in some Western European countries, activity has increased in Hungary. For the Czech Republic over 2005 – 2007, there were 11 varieties tested and in Poland there were only 5¹², perhaps showing that Hungary is more active than its Eastern European neighbours in pre-commercial development despite the stringent controls imposed by government.

Since 1999 a comprehensive law on GMOs has been in place in Hungary, complying with EU Directive 90/220. Article 10 of Hungary's Gene Tech Act XXVII, allows for the creation of genetic-protective zones, taking into account "flowering-biological features of the GM and the effected plant species, the environmental and climate relations, the other features of the GM and the effected plant species and environmental and nature

¹² Figures from GMO Compass: http://www.gmo-compass.org/eng/agri_biotechnology/field_trials/207.belgium_field_trials_gmos.html

protection."¹³ Hungarian law therefore exceeds the requirements specified by EU directives 90/219/EEC and 90/220/EEC.

On September 18th 2006, the Regulatory Committee of the DG Environment of the European Union voted against removing Hungary's moratorium on genetically modified corn variety imports. Meanwhile, the Government of Hungary is actively defending its moratorium due to what they argue is a lack of coexistence legislation to regulate the simultaneous production of conventional, organic, and biotech crops. Relevant committees of the Hungarian parliament have discussed a draft coexistence regulation with general parliamentary debate on this legislation which began on October 16th 2006.¹⁴

2.5. Conclusion

This chapter has described the main historical events that have shaped the science system in Hungary. The story begins with the soviet politics that influenced the organisation of the Academy. But also demonstrated is the relative in dependence of Hungarian scientists which led to an advanced state of the biology sector. Transition generally had a detrimental effect on the science system through lack of investment, attention of government on relevant policy, etc. though the gradualist approach taken may have allowed old links between people and organisations to remain.

The legacies as described by section 2.2. which remain from the time before and during communism can therefore be summarised as;

¹³ <http://genet.iskra.net/en/hungary>

¹⁴ <http://genet.iskra.net/en/hungary>

- An inherited system that is still in part structured according to the soviet model. This means that there is a separation of teaching from research and a separation of research from management.
- A biotechnology sector that at the outset of transition, was more advanced than any other CEE country.
- Forward thinking and relatively independent biologists.
- A research and development sector that is still mainly publically funded.

The legacies as described in section 2.3. that remain as a result of the transition process can be summarised as:

- A lack of connection with private and industrial partners due to the shrinkage of industry.
- A reluctance of the Academy to adjust due to a defensive approach having been adopted throughout the years of transition.

The current state of the biotechnology system has been assessed in more recent times by two studies. Bross et al finds that there is a requirement for an improved legal and regulatory system, a need for more funding and a limited role played by industry. There is also a lack of demand for biotech products and insufficient public debate in the country. However, Hungarian biotechnology has maintained a good quality of human resources. A premature conclusion of the report, in light of the national moratorium on GM crop commercialisation that would come later, is that crop biotechnology is in a relatively strong and stable position. Rafols in a quantitative report covering 2002-2005 estimates overall figures for biotech. He credits Hungary with the largest biotech sector in CEE but notes a shift from agro-biotech to pharmaceuticals for certain actors such as the transnational

corporations which is consistent with the assumptions made about the moratorium. There are various programs and funds administered by the government which are employed as tools designed to encourage applied rather than basic R&D in biotechnology.

The chapter ends with a summary of the most recent events which effect agricultural crop biotechnology in Hungary. Accession and the subsequent defensive position adopted by the national government highlights the main problem for the sector. The remainder of this thesis will investigate in more detail the factors that shape the agribiotech system and how the sector is adapting to cope with the problems outlined in this chapter.

Chapter 3: The Innovation System in Theory and the Role of Institutions

3.1. Introduction

Chapter 2 introduced the context, background for the study and the relevant history of science and technology systems in Hungary. It described the structuring of the economy and the science system under central planning, the relative independence of the Hungarian Academy of Sciences and the tradition of biology and pharmaceutical science that was maintained throughout the Soviet era. Transition was a structural change that was accompanied by severe funding shortages. Unsurprisingly the science system, which remains largely government funded, experienced and is still experiencing pressure to adjust to a new environment.

The previous chapter sketched a broad picture of the science and technology system relating to the Hungarian agri-biotech sector and its evolution over time. The aim of this chapter is to identify the central concepts for analysis within what has been termed so far as the ‘science and technology system’. These concepts will be key to understanding specifically the factors that effect innovation as a specific idea in agricultural crop biotechnology rather than simply the progression of the basic underlying science. Identification of the relevant concepts will first be drawn from a body of well founded literature that describes ‘typical’ or western innovation systems. The chapter will then revisit the peculiarities of Eastern European science and technology innovation systems and in the light of this more recent literature, discuss the evolution of the concepts being analysed and their likely implications.

3.2. Analytical Concepts

3.2.1. Background of the Theory

The purpose of this section is to explain the choice of theories used, why I looked towards evolutionary economics for an explanation of innovation in this sector and how technology and innovation were first defined, used and explained by the early academics and writers in this field. In doing so, there is revealed a justification for using a qualitative micro approach to the study of innovative capability.

In searching for an explanation of a perceived phenomenon, it is somehow natural to gravitate towards bodies of literature that are not entirely alien, to areas of study connected with previous experience and background. I therefore choose to search within the field of economics as a starting point for an investigation of the concepts important for a study of innovation.

Amongst the earlier writers recognising innovation as being of economic importance was Schumpeter. His major works in the 1930s and 40s theorised that capitalism and entrepreneurial activity created a dynamic economic environment, causing shifts in the allocation of resources and driving economic growth. His ideas however, were pushed out of fashion in later years by the contemporary neoclassical economics which modeled the economy on a static equilibrium (Nelson, 2007). In the neoclassical tradition, Solow (1956), Harrod (1939) and Domar (1947) explained technology as a public good and technical change as an exogenous factor, a “factor of last resort” causing the changes in long term economic growth where none others could be found. When empirical work

carried out by Solow in 1957 and Abramovitz in 1956, termed “growth accounting” found that the unexplained share of long run economic growth tended to be very high, interest in technological change increased. Meanwhile, Kaldor (1957, 1970), Verdoon (1949) and others working in the post-Keynesian tradition began to think of technology as an endogenous, private rather than public good. As such, technological development was associated with a cumulative learning process leading to knowledge that is specific to the agents that develop it, not easily over-spilling to other agents or nations (Verspagen, 2007).

Progress continued into the 80s and 90s with the emergence of two new major approaches to the study of innovation and economic growth. Firstly, in the neo-classical tradition, is the endogenous growth theory approach. Secondly, the evolutionary economics approach, inspired by the earlier work of Schumpeter. Evolutionary theory in economics mirrors Darwins studies in biological evolution. Innovations are seen as an important novelty generating process, though are not as in Darwinian theory, random mutations. Survival in the user market parallels a selection process. Generally speaking, both approaches agree on the importance of innovation and technology, though endogenous growth theory favours quantitative modeling methods while the evolutionary approach shows appreciation for the “micro-complications of the innovative process” and applies a more eclectic analysis (Verspagen, 2007, p.45).

It is work within the latter evolutionary economics approach that this study will draw upon to identify and explore relevant concepts. From the history of the science and technology system presented in the preceding background chapter, it is possible to see that there has been an accumulation of scientific expertise and the development of certain competencies.

There is a demonstrable trajectory and evolution of science in the Hungarian system shaped partly by its own internal forces and the momentum of scientific expertise, but also there is selection and applied pressure from external sources such as funding constraints, political ideologies etc. Innovation and competence for innovation cannot be simply pushed to the sideline as an exogenous factor, it is the central concept of this study and therefore requires methodology designed to investigate it as such. In terms of methodology, I might also add that the resources and context under investigation are not conducive to a quantitative modeling exercise, as would be favoured by the neo-classical approach. This will be discussed further in the next chapter.

3.2.2. The Main Relevant Categories Stemming From Evolutionary Economics

From the general evolutionary economics approach a number of other approaches have been elaborated to more specifically describe and analyse how innovative technologies are created and diffused. These include:

- a) National Innovation Systems (NIS)
- b) Technological Systems
- c) Socio-Technical Networks

By drawing on the work of authors such as Freeman (1987), Smit et al (1998), Edquist and Johnson (1997) and Lundvall (1992), these categories can be described further:

NIS literature presents less of a formal theory, but more a conceptual framework for analysing country specific factors at the macro-level. It considers in detail the concepts of innovation, learning, system and nation. The nation state is the main boundary, encompassing analysis of all influencing macro-level variables such as the R&D system, the role of the public sector and public policy, inter-firm relationships, the structure of the financial system and the education system. The shortcomings in the NIS framework are perceived as being a failure to take into account the supply side or the demands of consumers, and the relevancy of the nation state in an age where science and technology production is becoming increasingly globalised (Senker, 1999). NIS was defined early on by Freeman as “the network of institutions in the public and private sector whose activities and interactions initiate, import, modify and diffuse new technologies” (Freeman, 1987, p1). His 1987 work stated that a national innovation system with limited resources may be able to make rapid progress. This suggests that it is not merely the quantity of research and development that is carried out which enables technological development and economic competitiveness, but something more tacit in the institutional arrangements that are a major determining factor. Freeman goes on to demonstrate this by example of the NIS in Japan and the importance of the policies set out by the Ministry of International Trade and Industry.

A ‘Technological System’ combines the institutional elements of the NIS approach with the notion of ‘techno-economic space’. This describes the space in which innovation occurs with not geographical boundaries, but boundaries that are formed from the functional relationships of the sector. “I.e. related not only to the functioning of the innovative act of the production sub-systems, but also of the market (both domestic and foreign) and the

institutional infrastructure.” (Leoncini and Montresor 2003, p1). Though there appears to be much overlap with the NIS framework regarding the inclusion of institutional elements, the focus is very much at the micro level and the application of knowledge rather than its generation and diffusion (Senker, 1999)

The socio-technical network approach aims to integrate economic perspectives on exchange, technological collaboration and organisation with social perspectives on the cultural setting within which firms operate. Smit et al. (1998) demonstrate that the development of a technology is a co-evolutionary process of both technology and networks which come together in what they term ‘socio-technical network’. The networks studied under this approach involve relatively autonomous entities such as organisations, human and non-human actors, which are interdependent on resources and information that flow between them. A main advantage of this approach is that it recognises the importance structure while leaving room for individual and strategic action. Resilience is created by network actors who act according to what is the commonly accepted view of the network function, thus reinforcing certain patterns of behaviour. This approach also gives consideration to the effects of exogenous interactions from actors who are simultaneously part of other networks and who may create an important destabilising force. Resilience implies that technological developments which are congenial to the shared functions of the network will be accepted and so technical change will occur incrementally. The more complex is a socio-technical network, the more likely it is that any proposed change will be problematic for one or more of the actors. Dedicated network builders, which may be users or producers, play a crucial role (Smit et al. 1998). This approach frames an ongoing debate on whether technology is constructed by society or whether society is shaped by

technology. Again, many elements are shared with the NIS and technological systems approach with the inclusion of economic factors, social elements such as the nature of interaction between organisations and learning capabilities to achieve technological change. In contrast to the NIS framework which focuses on all networks in a country and the effects of policy, the socio-technical network approach may explore beyond national boundaries and looks at the construction of networks. The technological systems approach subsumes the main elements of the socio-technical approach, but there is at least one notable difference; that is the economic development focus of the former, and the identification of agents responsible for technological shaping in the latter (Senker, 1999).

There are elements in all three approaches which are necessary to incorporate into this study. Since the innovation networks are likely to overspill national geographical boundaries, the functional relationships which extend beyond the national, and their role in innovation are of interest to me. Resilience of the network and adaptability are also important in answering the research questions.

In addition to the national politics that currently prevents commercialisation of any GM crop in Hungary, the history of the science and technology system and current policy that effects the system (as discussed in the background chapter), means that the national context is important to this study. The NIS framework is therefore particularly suitable as an analytical approach to take account of these factors. The NIS framework was developed from studies of capitalist economies where the private sector is instrumental to innovation. In a study of Hungary there may be certain attributes connected specifically with systems that heavily feature the public sector or indeed the absence of the private sector. Literature

that might contribute to highlighting these attributes are drawn from studies of the ‘triple helix’ detailed below. Lastly, in reference to the previous section (3.2.1), which concluded with the likely importance of the accumulation of knowledge, expertise and competencies in the formation of technological trajectories, the mechanisms that allow for the transmission of learning and culture will be important to this study. This work will then draw from other literary domains for example by using concepts such as epistemic cultures, (further detailed in chapter 7). The next section will examine specific work from the literary categories discussed above in order to define the concepts for operationalisation in the next chapter and for analysis in the remainder of the thesis.

3.2.3. Identifying Relevant Concepts From NIS and Other Literatures

3.2.3.i) NIS

Most authors commonly refer to three key elements within the NIS approach; ‘innovation’, ‘system’ and ‘nation’.

Various definitions of innovation exist, with differing points of emphasis. For example, innovation as defined by Nelson and Rosenberg is a “process by which firms master and get into practice product design and manufacturing processes that are new to them, if not to the universe or even to the nation” (Nelson and Rosenberg, 1993, p.4). Rogers defines innovation as “an idea, practice, or object that is perceived to be new by an individual or other unit of adoption” (Rogers, 1995, p.12). These are useful in the sense that they have a focus on technical change. An innovation in agricultural biotechnology is essentially the production of a new variety or scientific procedure. Either of these would require the

contribution of new and existing scientific knowledge. Clearly this type of innovation represents a technical change and so rings true with the definitions above. But in contrast to the definition above, this thesis is interested in that which is new to the whole scientific community and system, not just the individual firm or research organisation in order for the study to consider a wider picture than simply change at the micro level. Lundvall's work in 1992 emphasises that innovation is the outcome of a learning process in which economically useful knowledge is accumulated (Marsili, 1999). This definition contributes much to the understanding of innovation as a cumulative systemic process and in the context of this work would invite questions such as how do actors in the system collaborate to learn from each other? And so despite the plentiful contributions to the definition of innovation that can be found in the literature, it is still necessary to slightly redefine it for my own purpose, pulling these useful elements from pre-existing sources.

It is not the aim of this thesis to analyse the entire national innovation system, but to understand a certain part of it from a national perspective. The 'nation' element of the NIS framework is presented from different aspects by various contributing authors. Johnson (1992) discusses the dependence of innovative capabilities on interactive learning and communication which are in turn dependent on geographic and cultural proximity. Niosi (2002) suggests that there is a limit to how far knowledge can be transmitted due to the tacit nature of at least part of it. Authors such as Edquist (1997) and Lundvall (1992) stress the importance of national public policy and the structure of national production systems as influential factors in innovation (Marsili, 1999).

However, technology undoubtedly overflows national boundaries as production systems become more global. There are additional levels of supranational governance which in the context of this study must also be considered. Hungary joined the EU in 2004 and so GM crop production has not only national law to contend with, but European regulation and the governance of other important bodies such as the OECD, WTO etc. Edquist (1997) suggests that regional, national and supra-national systems of innovation should be considered as complementary levels of analysis. What will be interesting in this study is the partly contradictory governance of the national and EU levels regarding GM crop commercialisation, and how innovation occurs in this contested regulatory environment.

The third element of the NIS framework is the 'system'. Lundvall (1992) suggests that because of the importance of interactive learning and the diffusion of new knowledge, innovation needs to be addressed within a "systems approach" (Marsili, 1999). Building on the work of Freeman (1987) and others, Nelson and Rosenberg (1993) define the system of innovation as "the set of institutions whose interactions determine the innovative performance ... of national firms"(p.4). Metcalfe (1995) similarly provides a definition focused on the systematic nature of innovation and set of institutions which develop and diffuse new technologies, additionally including the importance of government policy within this framework. Perhaps the most useful contribution at this stage, in particular to explicate the use of 'institutions' and their meaning in the NIS literature, is the taxonomic approach developed by Edquist and Johnson (1997). They offer the following definitions: "Institutions are sets of common habits, routines, established practices, rules or laws that regulate the relations and interactions between individuals or groups" (p46) whereas, "Organisations are formal structures with an explicit purpose and they are consciously

created.” (p47) and furthermore; “Organisations are strongly influenced, coloured and shaped by institutions. Organisations can be said to be embedded in an institutional environment or set of rules.” (p.59). Edquist and Johnson further differentiate institutions as formal and informal, hard and soft, basic and supporting. The metaphor they develop describes organisations as players and institutions as the rules of the game.

In taking a NIS analytical approach to the investigation of Hungarian agri-biotech innovation, this study requires an investigation of the organisations, or formal structures that are involved in innovation in this national sector. There is implied, a sense that no single individual creates an innovation, that the creation of a new plant variety depends on many actors and organisations and flow and accumulation of knowledge between them. Central to the analysis is the concept of institutions. I expect that the form of institution, whether it is informal or formal, and the strength of the connection to regulate the quantity and quality of information passed between organisations that diffuse new knowledge contributing to innovation. There are two main types of institutional analysis that should be distinguished: firstly there are the arrangements and connections which regulate the flow of information amongst the organisations of the research and development system that is directly responsible for the development of the new technology or plant variety. Secondly, there are laws, regulations and policies at the national and EU levels which are formulated by policy makers and actors not central to the research and development system. The formation of these policies and regulations is a policy study and is not the central subject of this thesis. What is of concern is the impact of the laws, regulations and policy on the institutional arrangements between the central innovative actors of the R&D system. Essentially it is a study of the impact of one institutional level upon the other.

Alternative sub areas of literature have been developed which offer slightly different levels of analysis such as that on regional innovation systems (e.g. Cooke, 2001). In Hungarian agri-biotech the actors are few, they are not sufficiently clustered, regional policy with specific regard to the agri-biotech sector has not been developed (see chapter 5) and so there are no region-specific dynamics or relationships that would make a regional analysis worthwhile. The sectoral innovation systems concept developed by authors such as Malerba (2002), is an attempt to move to a mezzo level of analysis. However, the agri-biotech sector in Hungary is underdeveloped as a sector. The primary actors do indeed interact as will be discussed, but they exist at a single level – at the predevelopment phase of the technology. Because commercialisation is prohibited and the links with industry destroyed during transition, innovation and knowledge does not flow through a complete sector from product conception to market release as in many studied sectors. While this is not a study of the national innovation system in its entirety, it is important not to lose the ‘national’ as the policy context for the reasons described above, and so the national rather than sectoral innovation systems approach is preferred. An alternative but very useful frame of analysis is accomplished by the triple helix approach.

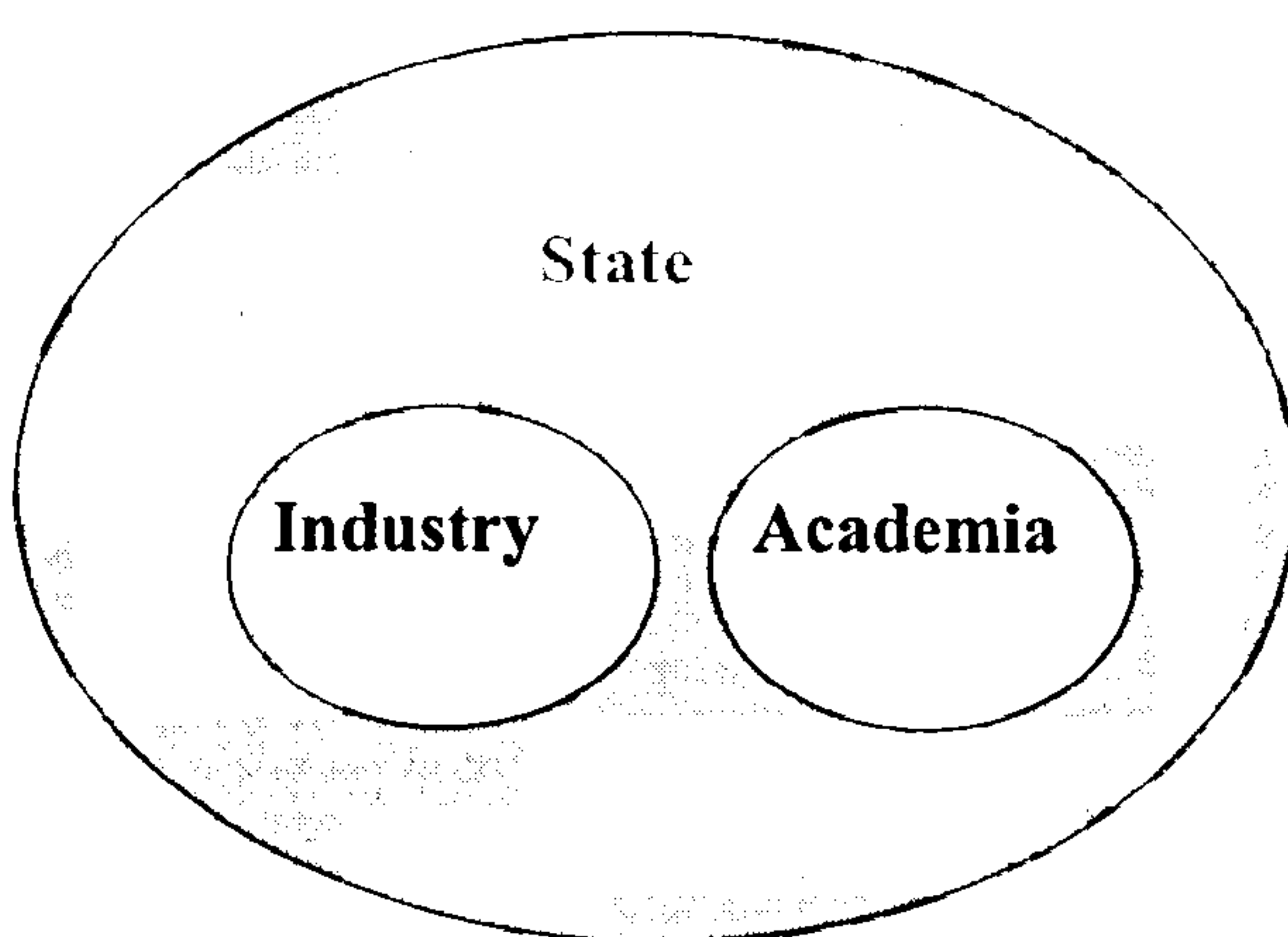
3.2.3.ii) Triple Helix

Institutions as defined above may reflect a number of different arrangements. The triple helix arrangement is built on the same premises as the NIS approach, with similar definitions being given to institutions, organisations, innovation etc. However, leading authors in the field such as Etzkowitz and Leydesdorff (2000) claim that the triple helix

model is analytically different to NIS in that it is not firms who are presumed to be the leading innovative actors, innovation is instead influenced by the arrangement between academia, industry and the state. Leydesdorff and Lengyel (2007) argue that using a triple helix framework allows a more specific analysis of the interactions of actors at the interface between academia, government and industry. It has therefore been so far used as a neo-institutional model, used to study the different network arrangements and configurations possible and the effects on innovation.

According to Etzkowitz and Leydesdorff, the advantage of considering the triple helix model is that it demonstrates a non-linear dynamic, i.e. an unstable ongoing transformation of the helices rather than presuming technology push or market pull forces to explain innovation. Figures 1, 2 and 3 diagrammatically represent various triple helical arrangements adapted from Etzkowitz and Leydesdorff (2000).

Fig 1. Triple Helix 1.



In figure 1, the nation state encompasses academia and industry and directs the relationship between them. The strong version of this model was found in eastern European countries under socialism and to a lesser extent in many South American countries.

Fig 2. Triple Helix 2

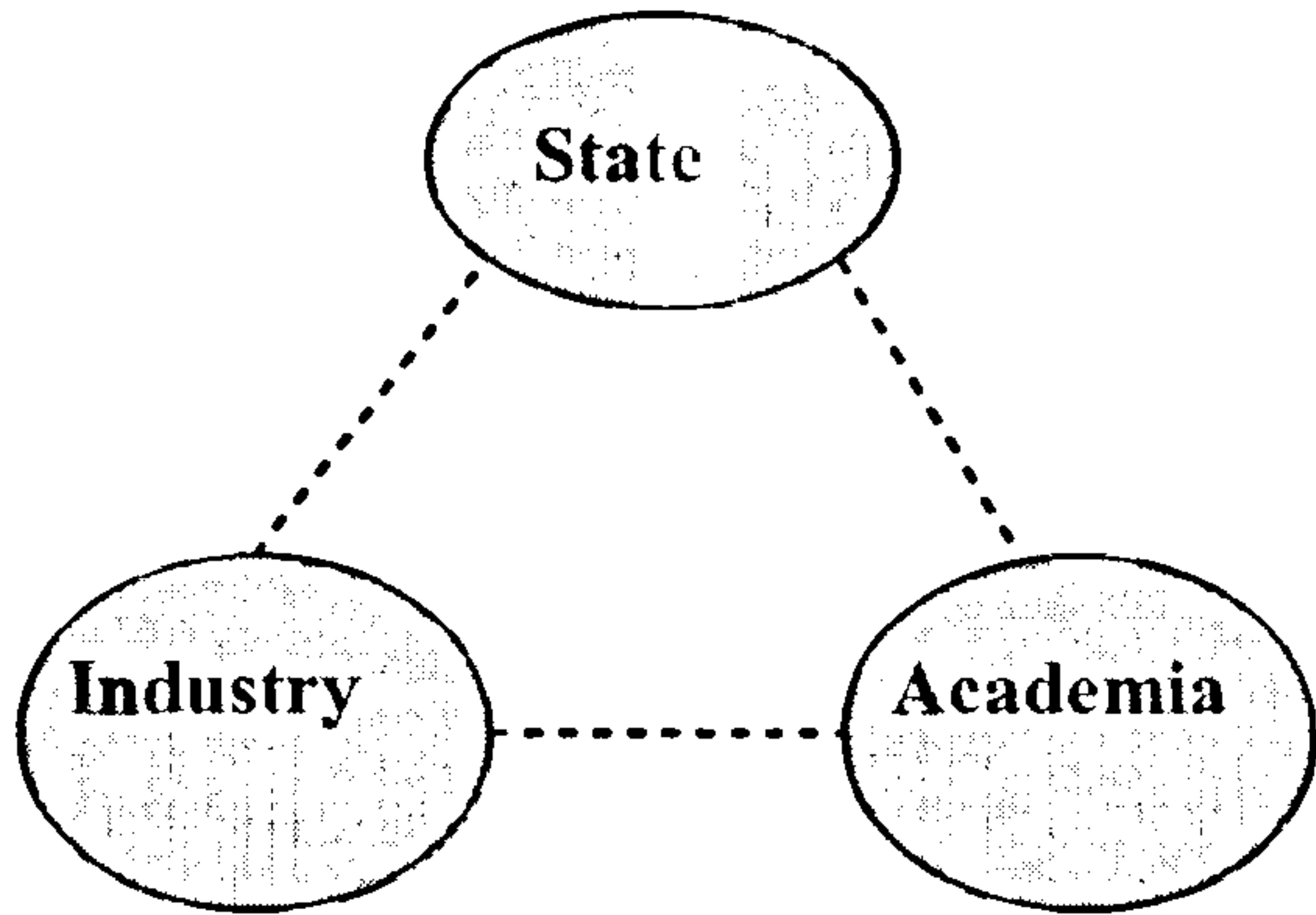
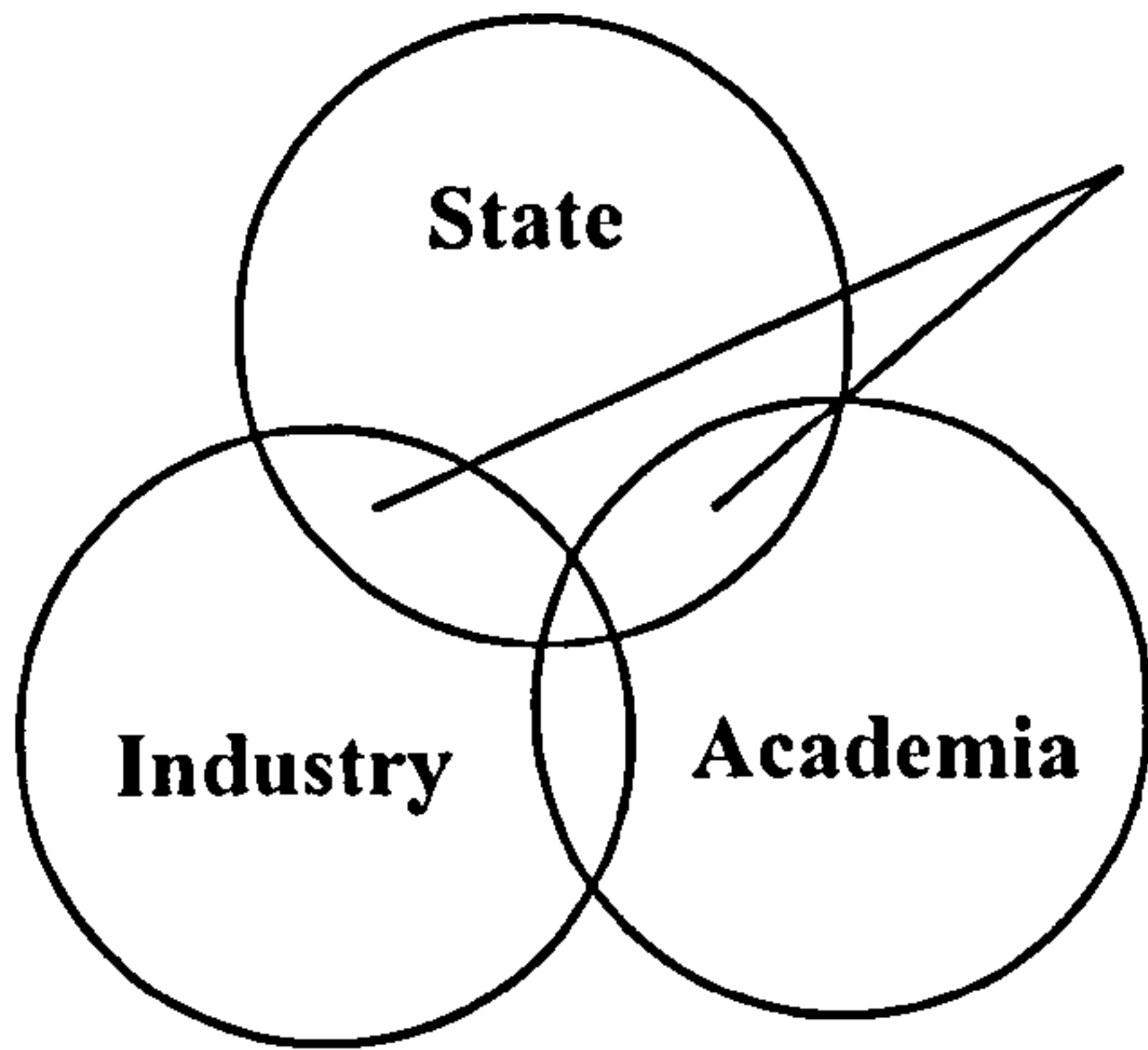


Figure 2 represents a “laissez-faire” model of relationships. There are separate organisational spheres with strong borders exemplified by countries such as Sweden and the U.S.

Fig 3. Triple Helix 3



Trilateral networks and hybrid organisations

Figure 3 represents a model which most countries are moving towards. Trilateral networks include strategic alliances between actors. Hybrid organisations are for example, university spin offs.

Triple helix 1 is regarded by the authors as a failed development model. There was too little room for “bottom up” initiatives and so innovation was discouraged rather than encouraged. It has also been termed the ‘etatistic¹⁵ model’ (Etzkowitz, 2002). Triple helix 2 is based on laissez faire policy, advocated in shock therapy to reduce the role of the state.

¹⁵“Etatistic Socialism is distinguished from other socialist systems in two ways. In contradistinction to many other socialist movements which contemplate the greatest possible measure of equality in the distribution of the social income between individuals, Etatistic Socialism makes the basis of distribution the merit and rank of the individual. It is obviously superfluous to point out that judgment of merit is purely subjective and cannot in any way be tested from a scientific view of human relations.”(Ludwig von Mises *Socialism: An Economic and Sociological Analysis*, 1922. trans. J. Kahane, Foreword by F.A. Hayek (Indianapolis: Liberty Fund, 1981).
http://oll.libertyfund.org/?option=com_staticxt&staticfile=show.php%3Ftitle=1060&chapter=103937&layout=html&Itemid=27

Triple helix 3 is seen as the optimal innovative environment with various inter-organisational alliances and cooperative arrangements and also new hybrid organisations forming at the boundaries. This outcome can be encouraged but not controlled by government policy (Etzkowitz and Leydesdorff, 2000).

A study of the variety of networks and the different institutional configurations of the actors is one aspect of a triple helix analysis. However, we can also consider the division of labour between the agents, i.e. the quality of the institutional arrangements between the actors. Practically speaking, this means how knowledge is diffused and controlled by the different agents. Leydesdorf and Lengyel call this a 'neo-institutional model' by looking at not simply the network of actors and organisations that interact, but the totality of the relevant actors. Neo institutional models consider how organisational structures and networks come to reflect institutionalised rules (Dimaggio and Powell, 1983).

In other words, more important than the mere presence of agents in the configuration, is what they do and the functions they perform. The networks are the infrastructure of the national innovation system, which allows the facilitation and exchange of knowledge, but the underlying knowledge base, the creation of the knowledge in the first place, is shaped by the division of innovative labour at the national or regional level (Leydesdorff and Lengyel, 2007).

3.2.3.iii) Role of Academia and Universities

There is further research which adds depth and validity to the idea that the academic sector is important in the research and innovation process. From P.A.David (2007) we can add that innovative capability in academia is not a recent aim of society but capability can be thought of as underpinned by a history and an establishment of relevant institutions. It was in the 19th century that Wilhem von Humbolts proposed reform of German universities led to research becoming established alongside teaching in Europe's higher education system. The Humboltian model was subsequently imported into American universities and proved to be immensely successful. The progressive integration of research with advanced instruction in universities was imparted and reinforced through generation after generation. This ethos of 'open science' became governed by what David describes as informal behavioural norms.

With regards to the institutional arrangements as defined by the NIS perspective, more recent literature has detailed the role of academia. Koschatzky for example states that universities have an important role as knowledge generators and knowledge exchange agents. In an innovation system they have two main roles. Firstly to manage the knowledge base; to develop a common knowledge base in the region and diffuse knowledge through education and demonstration or transfer of technological or scientific solutions. Secondly, they are providers of expertise. In this case universities and research institutes are in contact with a single actor to provide a specific solution under contract or consultancy arrangement to a specific problem. According to Koschatzky, both bilateral cooperation and multilateral networking relationships are possible between research institutes and companies. The

spectrum ranges from a) ‘soft’ transfer activities such as staff transfer as occurs during any type of collaboration, short or long term and technical-scientific training. Also information transfer such as through the preparation of publications, patents etc. And b) contracted transfer activities such as research and development cooperation ranging from contracts and consultations and the foundation of new firms to commercialise their own and others research and technical development (Koschatzky, 2002).

Further attention to the role of European Universities has been given in strategies announced in 2000 at the meeting of EU Council Ministers in Lisbon and subsequently elaborated at the Barcelona meeting in 2002 following suit in the progress made by other policy initiatives implemented elsewhere, for example by the OECD and the Bayh-Dole act in the US in the 80’s. The effects of the OECD and US acts were to codify the terms upon which institutions conducting state sponsored research could seek intellectual property rights. It resulted in the EC *Communication* of February 2003 on “the role of the universities in the Europe of knowledge.”¹⁶ The commission communication found fault with universities for failing to realise their innovation potential and to make it a priority (David, 2007).

There is ongoing debate about the role of universities and academic organisations in European innovation systems. The proponents of the Humboltian idea argue that to deliver the best standards in teaching requires cutting edge research to be on-hand within the same organisations. This type of arrangement might well encourage university spin-off firms, entrepreneurial activity and other such activities that are generally thought to contribute to

¹⁶ European Commission, Communication from the Commission: The role of the university in the Europe of knowledge, COM (2003) 58 final. Brussels: Commission of the European Communities (5 February) 2003.

an innovative economy. However, authors such as David (2007) argue that Europe should be building new elements of an organisational infrastructure for science based innovation instead of setting “new and inappropriate tasks” for its existing academic organisations. He asserts that emulation of the US Bayh-Dole act is not appropriate since it has been costly for US universities to implement and generally its effectiveness has been mis-perceived in European policy circles. He suggests that in fact the ‘innovation gap’ is caused by a lack of private sector R&D, which is in turn a consequence of a restricted supply of innovations and a low market demand for inventions (David, 2007). These general arguments feature heavily in Eastern Europe where the science system is in a state of transition, a point that will be further discussed in the next section.

For now, leaving aside the debate on what should be the role of academia, I return to the more pragmatic question of what *is* the current role of academia, what is the nature of the relationships between academia and industry, and how does it effect innovation. A study by Etzkowitz in 1998 used data from over 150 in depth interviews with academics in four disciplines (one of which was biology) in order to answer a somewhat similar question. His findings shed light on the above mentioned trilateral networks and hybrid organisations that form at the interface between academia and industry. Etzkowitz acknowledges the existence of the traditional view of academia by firms; that it is primarily a source of human capital and future employees, and secondarily a source of knowledge. A traditional view of knowledge flow from academia to industry frames the problem in terms of ‘hydraulics’, with knowledge in academia seen as a ‘reservoir’, controlled by ‘dams’ and ‘gateways’. And so the role of the academic institution, in agreement with David, should maintain a traditional function interacting across distinct boundaries. In practice Etzkowitz

finds 4 groups of firms in his US study. The first, comprising mostly of large multi-national firms, is gradually changing, though are based on a system whereby R&D was traditionally internalised and any academic research was obtained through consultation and liaison programs. The second group of firms, typically smaller and based on low and mid-level technologies, have few relations with academia. Where these exist they are likewise informal and achieved via consultancy or trouble-shooting services. A third group of firms is described as having grown out of university research and are still closely connected with their original organisation. And finally a fourth group of firms, mainly older, have externalised their R&D, have developed joint collaborative programs with universities or seek to import technologies from them. To summarise the dynamics within the system; “As industrial sectors and universities move closer together, informal relationships and knowledge flows are increasingly overlaid by more intensive, formal institutions” (Etzkowitz 1998, p825).

3.2.3.iv) Links Between University-Government-Industry

Fluidity of the boundaries between sectors such as firms and academia may be promoted by what might be called ‘boundary actors’. Etzkowitz for example discusses the emergence of the entrepreneurial scientist. Far removed from the traditional perception of the scientist as an “unworldly but determined individual” solely motivated by the accolades of peer recognition, a relatively small number of scientists, who are usually the most successful researchers in their field, are increasingly working with external organisations in order to find funding to make up for shortfalls in public sector spending (Etzkowitz 1998, p.828).

This project uncovers further examples of boundary actors and their role in the Hungarian agri-biotech system will be discussed in chapter 5.

Nelson (2007) suggests that original work on NIS in the 80s and early 90s has ignored the role of the individual. Whilst not refuting that sophisticated human practice is the result of long term achievements from a long-run evolutionary process, he suggests that discussion around the strength of individual human knowledge as a contributory factor has been “repressed” (Nelson 2007, p.32). The character and strength of individual human knowledge does effect the evolutionary process. It allows the researcher to identify potential pathways, identify dead-ends and evaluate new practices. Innovations are not always the result of the system or actors creating random or “blind” changes as in the Darwinian sense as described in section 3.2.1 by Verspagen (2007), but can be the result of individual problem solving activities (Nelson 2007, p33). This is developed as a key concept in chapter 6.

3.2.3.v) Paradigms, Lock-ins, Path Dependency, Trajectories

The last part of this section will review the literature that discusses lock-ins, path dependency, trajectories and path breaking technologies. These concepts will prove to be important in the following chapters because the idea of trajectory and lock-in reduces uncertainty in the predicted direction of technological progress. Identifying lock-in and path dependency in the Hungarian agri-biotech system, will to an extent allow us to see the problems that innovative actors and organisations face and how public policy is assisting to solve these problems or not. For example, if the problem appears to be lock-in to a

particular technology or direction, the question may be asked, is policy attempting to address the problem by encouraging research or providing funding in alternative directions? To discuss these concepts I stray beyond the confines of the NIS literature and consider sources for example from the Technological Systems approach among others.

Path dependence is perhaps the development of previous theoretical work. For example Nelson and Winter describe Markov chains; “[T]he condition of the industry in each time bears the seeds of its condition in the following period. It is precisely in the characterisation of the transition from one period to the next that the main theoretical commitments of evolutionary theory have direct application. However those commitments include the idea that the process is not deterministic; search outcomes, in particular are stochastic. Thus, what the industry condition of a particular period really determines is the probability distribution of its conditions in the following period” (Nelson and Winter, 1982, p.19).

Antonelli (1997) defines path dependency in the following terms; “Path dependence defines the set of dynamic processes where small events have long lasting consequences that economic action at each moment can modify yet only to a limited extent” (p643).

Antonelli argues that path dependence should be considered a macro-economic process and so each individual agent does not have a full understanding of the sequence and timing of each stage. Time matters on two accounts; first it is a source of uncertainty about consequences of each action, but secondly time matters because of irreversibility. Antonelli further makes the distinction between path dependence and past –dependence. Unlike past-dependence, a trajectory cannot wholly be explained by original events. There is a cumulative effect of actions at each point in time. It is therefore systemic and dynamic,

focusing on the process of change. There are two underlying causal mechanisms for path dependence; indivisibility and irreversibility. The concept of irreversibility is well developed within the field of industrial economics. It stems from switching costs (the cost to producers and consumers of changing their mix of products), and sunk costs (the losses made if a decision on a purchase is reversed). Indivisibility of production factors results in low levels of appropriability for example (Antonelli, 1997). This means that there is interdependence among users and producers of an innovative activity. If an innovation cannot be wholly appropriated by the user or secondary innovator, the original producers continue to play a role in the diffusion or innovation process leading to the clustering of innovative activities. Low levels of appropriability and learning are described by Antonelli as being general problems within the classification of indivisibility.

Amongst the primary work on technological trajectories we might mention Nelson and Winters (1982) identification of generic technologies, whose natural trajectory of evolution encompasses a whole set of interconnected radical innovations (Perez, 2002). Elements of this idea can be found within Dosi's 1982 definition of technological paradigms: "technological paradigms are 'models' and patterns for finding solutions to selected technological problems, based on selected principles derived from natural sciences and on selected material technologies" (Dosi, 1982 p.152). According to Dosi, a paradigm includes theoretical and methodological approaches, an agreed way of defining a problem and an agreed set of skills and competences required to solve the problem. Practitioners though can become committed to their paradigm, the way they see understand and carry out their work and can become locked-in to it, becoming resistant to new or alternative methods (Green et al, 1999). From technological paradigm, Dosi develops the idea of a trajectory. "We will

define a technological trajectory as the pattern of “normal” problem solving activity (i.e. of “progress”) on the ground of a technological paradigm” (Dosi, 1982 p152). Perez was the first to use the term techno-economic paradigm (TEP) in 1983, subsequently adopted by Freeman and others. The concept of TEP features the “pervasive effects throughout the economy, i.e. not only leads to the emergence of a new range of products, services, systems and industries in its own right; it also effects directly or indirectly nearly every other branch of the economy” (Freeman and Perez 1988 p.47 cited by Green et al, 1999).

Nelson (2007) presents a similar perspective. He draws upon the example of the development of research based pharmaceutical companies after WWII and suggests that change in physical technologies can cause change in the surrounding organisations and environment. Nelson in addition makes a definite distinction between physical and social technologies and remarks that “In contrast to the calculation, experimentation and deliberate and reliable testing that accompanies innovation in physical technologies, the same cannot be said for social technologies; to implement a new business practice or public policy... institutional learning seems to be just much more difficult than learning regarding physical technologies” (Nelson, 2007, p37). Green et al (1999) adds that there can be match and mis-match between new generic technologies and institutional arrangements that accompany their take off. ‘Boom’ periods occur where there is mutual reinforcement between the technological and institutional changes. The reason for mis-match between a new technology and its institutional environment, is proposed by Von Homeyer from a study on EU governance: “Most of the time EU governance will be relatively stable. If anything, gradual shifts in underlying conditions, such as economic and technical developments or environmental tenants will have a mediated and delayed effect. The reason

or this is that institutions are conditioned by the past. More specifically institutional reproduction tends to be path dependent” (Von Homeyer 2004).

Does the concept of trajectory or TEP reflect in the development of agricultural biotechnology of the type investigated in this thesis? It is certainly the case that within the biological sciences there is a trend towards molecularisation and genetics. Not only are the cause of problems diagnosed via an explanation of genetic variation in plant populations, but the solutions to perceived problems are also delivered by the offering of possible genetic alterations. This is expanded on in chapter 7. Related technologies have been developed to improve molecular level diagnosis and solution delivery as well as expertise surrounding the technologies. These changes have percolated through the research sector and have altered the higher education sphere, for example by the addition of courses on molecular biology and molecular biology techniques to university biology courses. The changes have also to an extent effected the suppliers of laboratory equipment, food producers and suppliers who are presented with these new products, and politicians and society who debate and produce policy concerning them. There is I believe, the development of a paradigm, a trajectory and a certain degree of lock-in. By making the distinction between the development of the physical technology and the surrounding social institutional environment (in the same way as Nelson, 2007 and Green et al, 1999) i.e. public policy and regulation, it becomes easier to investigate the affects of one institutional level upon the other.

Given the broad acceptance of these concepts as relevant to the thesis, I would like to now elaborate by asking the question, what are the mechanisms by which path dependence,

technological trajectory and lock-in occur, and what are the general problems? The specific problem regarding these concepts and the way they effect systems in Eastern Europe, will be left to the next section.

Niosi (2002), puts forward six primary causes of path dependence and lock-in:

1. Increasing returns to scale. In industries characterised by increasing returns, the first firms to enter may impose their technology and thus dominate the market. New entrants will start under lower production scales, less experience and thus higher costs.
2. Network externalities. Early entrants may diffuse their standards and exclude future competitors, whatever the quality of their solutions.
3. Sunk costs. Existing firms may get locked-in due to their past investments in technology.
4. Contracts. Institutions are devices that reduce uncertainty and contracts make explicit expectations and performance requirements. However, contracts tend to “freeze” organisations.
5. Human learning. Organisations invest in codes of communication, human capabilities and so on. These sunk costs are of a specific intangible type.
6. Economic systems, organisational and institutional arrangements display “multiple equilibria”. A single arrangement may be suited to a particular time but may not be suited to a changed environment of the future or past. Firms that become locked in to an arrangement of a particular time may become ineffective or inefficient in the future (Niosi 2002, p294).

In a study originally developed for examining research on laboratory animals, Frank (2005) describes the large number of sources which lead to technological lock-in. Among them, the positive feedback loops created when firms gain experience in the use of particular technologies, creating a 'selectional advantage' associated with that technology, guiding further development. Frank in a similar way to Nelson and Green et al discussed above, makes distinct the concept of 'institutional lock-in'. According to Frank, this can result from the actions of self-interested stakeholders such as academic departments, private testing companies, equipment suppliers, government agencies, NGOs etc. It can also result from the legal environment including laws, regulation and the wider institutional environment, so giving rise to inertia. Such inertia leads to the establishment of paradigms and techniques which remain in place when they are no longer "optimal"¹⁷ (Frank 2005, p564). A final intriguing proposition put forward by this author that might be considered in later chapters: "The behavioural component of lock-in is probably the most subtle yet the most powerful. Even if agents ignored self-interest, they are likely to make decisions biased by their previous experience, psychology, and the nature of the institutions" (Frank 2005, p562).

The difficulties of path dependency and trajectory have been recognised by many authors. Niosi (2002) goes so far as to say that most of the inefficiencies and ineffectiveness of national innovation systems are related to path dependence and lock-in situations. The problem is framed by Levinthal in the following way: "Firms have been recognised as being bound by their path dependent trajectory of capability development. Thus, firms technical capabilities are on one hand, a source of tremendous strength, providing the basis

¹⁷ "optimal" has specific connotations particularly in reference to economics literature, but is used here by Frank in a non-specific way.

for competitive advantage. At the same time, these firm-level technological trajectories are also highly constraining”. (Levinthal 2007, p.294)

Radosevic however argues the NIS rather than the mainstream perspective (which views all legacies as deterrents and obstacles to change): “Legacies are seen as being dual in nature, being simultaneously a ‘resource’ as well as a ‘constraint’ or a ‘heritage’ and a ‘source of creation’. Path dependency combined with radical change creates an evolutionary process in which legacies but also novelty, play a role in future outcomes”. (Radosevic, 1999, p.280)

3.2.3.vi) Path Breaking Technologies

According to Tait, (2007) GM crop biotechnologies have been recognised as a ‘path breaking’ technology. A path breaking technology would challenge either the innovation strategy, markets or the regulatory system, which GM crops certainly have done. I would suggest that there has been a reorganisation of societal institutions around the technology, and possibly a mismatch between physical technology and the social institutional environment in the way suggested by Green et al, discussed above. Tzotzos and Skrabin (2000) state that innovation in biotechnology must be accompanied by dynamic adjustments at institutional and social levels. (e.g. industrial and science policy shifts, skill and education upgrading). Adjustment failure can therefore occur due to systematic rigidities, leading to slow innovation. Government policy which effects for example skills development, funding or regulation, unless it evolves in a way to facilitate innovation, may be counted as a rigidity. The evolution of the regulatory system and the global variations

that have arisen in the governance of GM crops have been the subject of much academic attention and so will not be the focus of this thesis. However, given that there does exist regulation, this work may question why there is a mismatch between the physical technology and its innovation. i.e. what evidence is there that there is no 'boom', no reinforcement of the innovation pathway by the regulatory environment as it exists in Hungary and what are the effects of the lack of reinforcement on innovation? Likewise much has been written about public perception and the consumer market with regards to GM crops. It will not be necessary to cover this literature or repeat the studies on public perception. I take the view that given the absence of a market for domestic producers, there is again a mismatch between the technology and the market as an institution. The affects of this mismatch and the absence of a market on the innovation system can be investigated.

3.3. Expectations of Innovation Systems in the Eastern European Context

3.3.1. The Literature Describing the Innovation System Before Transition

The patterns of organisation and diversity of actions which normally create different systems of innovation were greatly reduced by the centralised socialist system. Technical change originated and was pushed from a single sector linked vertically to various industrial enterprises. This sector, given different names in different countries was usually involved not only in research and development but also in design, engineering and problem solving. It was according to Radosevic (1999) a 'linear innovation model' in which technology flows were constrained within individual sectors. Technology was perceived as a freely available information-like commodity which emerged rather neatly from R&D and could transferred to production units (Pavitt, 1997). Production and users were not

considered as being a source of innovation or improvement. Enterprises in the western sense didn't exist, they were merely production units. Other business functions such as marketing and finance were similarly 'outsourced' to ministries or institutes or were (with the exception of R&D) maintained at a very basic level in house (Radosevic, 1999). There was an absence of small specialised suppliers which are usually beneficial to an innovation system due to their detailed knowledge of specialised applications and diffusion of best practice across firms and sectors (Pavitt, 1997).

A central role was played by the Academy in CEE innovation systems. A broad description of the academy and its history are presented in chapter 5. The structure, function and activities of the academy reinforced the sequential linear innovation model and sectoral segmentation. As described by Balazs in 1997: "The research network was based on the principles of central planning and on the linear development model. They organised research institutes in every discipline under the leadership of an academician. The director (academician) was the head of the hierarchy. The institutes, and indeed the whole network was vertically organised through departments and research groups" (p165). Radosevic adds that the academy is not only an expression of the systematic characteristics of the socialist R&D system, but is also an expression of the path dependency that permeated the system (Radosevic, 1997).

Links between the basic research carried out by the academy and other sectors of the economy or even the research sector were weak. Balazs indicates some possible causes: "Application or industrial implementation are the professional interest of the researcher, and it was natural for East Europeans to follow up fundamental scientific results. But

industry was not interested in implementing these results. Thus researchers gave up trying to transfer their results...Academy research results were not presented in a way that firms could implement – which gave the firms a convenient excuse for inactivity” (Balazs 1997, p167). With the onset of shrinking government funding in the 70s discussions after much resistance, finally saw acceptance of the need to undertake applied science and contract research in order to supplement funding. While this might indicate the development of effective ties between the academy and industry, this was usually not the case. The work undertaken by the academy under these circumstances was usually at a low technical level and constituted problem solving or trouble shooting type activities.

There is then and now continuing debate over the role of the academy, universities and research institutes. The distinction between basic and applied science is at the core of this debate. What constitutes basic science and what are the additional social institutions required for a more integrated approach of basic and applied science to create an effective problem solving paradigm?

Radošević asserts that links between R&D and production were generally weak. However functional one way links running from R&D to production were more intensive. Actors were linked through complex hierarchical relationships. There were common systemic features regarding the strength of links within these hierarchies. Weak links included those between different ministries or different branches, those between foreign sellers and domestic users and lack of feedback from user enterprise to R&D and design institutes. System integration at the product and process level suffered particular difficulties. System integration at product level – production and continuous improvement requires the

integration of different functions – finance, R&D, engineering, procurement, production. In market economies this integrative function is carried out by producers or users, an actor which Radošević terms ‘network organiser’. In post socialist CEEs, the state sometimes took on the role of network organiser in an attempt to create a national cluster. In post transition economies Radošević argues that foreign firms have gone the furthest as network organisers. Process integration involves the organisation of innovation across several tiers of suppliers who contribute to production and innovation. Again, in market economies, the integrator or network organiser would be the producer or user. In the socialist period, it would be a government administration, or a design institute who would take on this integrative function (Radošević, 1999).

Informal networks also played a key role. They were essential in compensating for shortages of raw materials, spare parts, equipment and so on. Informal networks were an institution capable of negotiating relevant exchange. Under the socialist system formal contractual obligations were prone to failure, industrial managers therefore had to develop the ability to ‘get things done’. Managers were faced with a diversity of technological and organisational challenges, and the way to cope with these was to establish their own social networks (Radošević, 1999).

Despite this, there was still what I would describe as an institutional gap in the lack of a real market for innovation. Under the socialist system there was of course no appropriation of innovation rents, the conception of technological development was that of a free good (Radošević, 1999). As Gomulka explains; “Rapid innovation is incompatible with idealised (Marxian) socialism; such innovation not only sustains high inequality and competition by

constantly supplying any new products for a few, but also requires high inequality and competition as incentives” (Gomulka 1986, p.54). The effects of this are difficult to determine. It does however parallel in some way the current situation of GM crop development in Hungary, a country which has banned the commercial cultivation and therefore to an extent removed the market for innovation in this area.

Transition in the early 90s saw a decline in eastward oriented exports, falling income, falling industrial production, increased budget deficits, high inflation and unemployment. Economic uncertainties were aggravated by changes in legislation, ownership and industrial structure. In this uncertain environment firms and public organisations pursued only short term interests, largely forgoing long term investment strategies. Privatisation was not used as a strategic instrument for innovation and growth, but rather to increase budget income quickly. Neither was science and technology policy developed effectively as governments in CEE became preoccupied with crisis management at around this time. There was a clash between the elite academicians in power who wished to defend the status quo and the ‘privilege of science’ against the middle generation of researcher-managers who pushed for reform of the S&T system. In all CEE systems the effect has been the abandonment of the R&D sector by the government, by industry and by the market (Balazs, 1995).

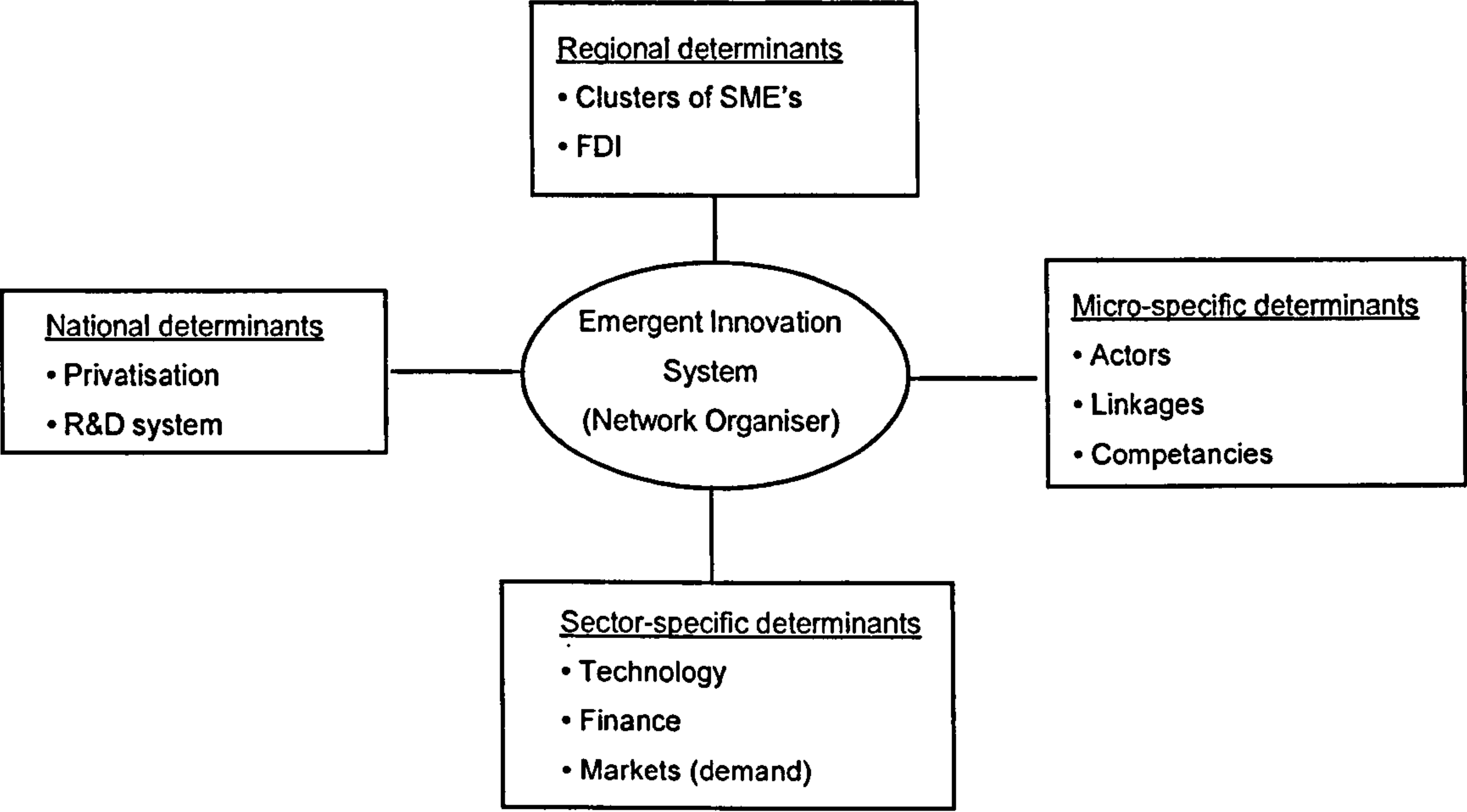
3.3.2. The Literature Describing the Innovation System After Transition

Hungarian academics (Inzelt 2004, Havas, 2002) divide transition into 2 phases, of which only the first has been completed. From an inheritance of a non-viable economy, significant change has occurred. A parliamentary democracy has been established and the most

important economic institutions such as commodity markets and a stock exchange. In 1990 state ownership was over 90% of the Hungarian economy, by 2000 this had been reduced to around 20%. However there remain many important tasks which include budget reform, harmonisation with the EU and the lack of an explicit innovation policy that is likely to hinder long term development (Havas, 2002). Pavitt (1997) points to a lack of policy coherence and a high level of economic, political and legal uncertainty, common to most economies in transition. Balazs (1995) explains that in the years shortly after transition, vertical and horizontal linkages remained broken and the S&T system underwent a period of ‘passive adjustment’: the strengthening and consolidation of the role of academic research institutes in the absence of government policy. Some ‘active adjustment strategies’ became apparent, led by individuals and heads of research organisations rather than the state in what is described as a policy vacuum. In this case research managers and technology-orientated entrepreneurs have formed alliances, associations and societies in an attempt to bridge the gap between academia and industry. In this 1995 work, Balazs does not extend to answering the question of whether all regions and sectors experienced this, to what extent, or what were the determinants. This may remain an appealing question for this thesis in its examination of the agri-biotech sector in Hungary.

Fig 4. presents a generic model formulated by Radošević (1999) in order to explain the determinants of post transition innovation systems.

Fig.4 Determinants of emergent systems of innovation in post socialism. Adapted from Radosevic (1999)



Micro specific determinants; the emergence of innovation systems in post socialist economies evolves around the reconstruction of enterprises as the main actors. The way enterprises develop their business functions and the character of the networks in which they are embodied will determine the NIS. Whereas in the previous system there were no feedback loops between suppliers and consumers, links now must become two-directional. Learning inputs from users can be fed into the technology innovation process but for learning to occur, a critical level of demand for technology by users is a pre-condition. By ‘competancies’, Radosevic means that enterprises must develop non-tangible and non-technological assets such as marketing skills, finance, management and organisation, network building capacities and so on.

Sectoral differences are also investigated by Radošević. The sectors that were given priority, typically those related to military industry, were given more development and production facilities. These sectors were still controlled centrally but were afforded more flexibility in planning and the means to overcome inter-departmental and intra-departmental barriers. These sectors had formal functioning networks despite overall systemic weaknesses. Studies of sectoral determinants suggest that the shape and pace of the restructuring process are also determined by technology and finance gaps. If the gaps are small, it might be expected that restructuring would be domestic-led. If the gaps are large Radošević suggests that the problem has often been resolved in CEE by surrendering control of the modernisation process to foreign investors.

National differences in S&T systems include the degree to which R&D activities were carried out in extra-mural organisations (R&D institutes) or in-house, the role of the universities, the role of the Academy of Sciences and the degree of 'openness' with regard to S&T co-operation with the rest of the CMEA or the rest of the world: "Post socialist national differences do not arise only from differences in national factor endowments and factor prices but also, and perhaps more so, from national institutional differences." (Radošević, 1999 p301). Radošević asks the question; what are the main national determinants of actors links and competencies? Different types of privatisation produce different structures of demand for R&D and technology. NISs in CEE will be shaped by the way enterprises reconstruct their links and embody innovation, but also by the way the state regulates interaction with MNCs.

There are also differences between civil sectors determined by technological, historical and organisational factors. Sectors differ for example according to whether a research institute handles all, or just part of the R&D and whether the factories are themselves also responsible for any design and development work. Particular arrangements evolved where powerful or entrepreneurial individuals played a role.

Radosevic (1999) concludes with the following: “In post-socialism, new patterns of links between enterprises, buyers, sellers, and foreign partners are proliferating. While patterns of innovation are becoming more sector specific and in that respect, more diverse, the rise of mezzo industrial groups and foreign firms as important network organisers indicates the possibility of widespread cross-sectoral knowledge links” (p.312). Clearly this gives prescriptive advice on what one may find in a study of sector specific innovation in CEE. It also offers justification of an investigation at the mezzo as well as macro level. Some of these factors will be carried through to the next chapter in order to focus the method around an operationalisation of the main concepts.

The current situation in Hungary is assessed by Inzelt (2004). There is an apparent dual pattern of innovation in Hungary. While there is some movement in certain sectors towards international collaboration and cooperative research with academic organisations, there is simultaneously a great majority of firms who are either not engaged in innovative activity or who refuse to see universities as crucial innovative partners. It is proposed that the development of an innovation-friendly business environment, complete with a reshaping of the government role, could take years, if not decades more in Hungary (Inzelt 2004). In a Hungarian Delphi survey of research scientists and engineers in 2002, it was apparent that

the issues affecting this group of innovators were non-technological ones. The top 10 Delphi statements referred to the importance of human resources, regulation and institutions (Havas, 2002). The Hungarian governments R&D policy “Science and Technology policy 2000” (see chapter 5), was judged to be “a sharp return to the good old linear model of innovation” and an overriding emphasis on the supply side (Havas 2002, p.385). Havas describes a current situation in Hungary where “history does matter. Indeed, the legacy of planning, and especially of the reformed economy, still has non-negligible impacts on the political and consumer “tastes” of people, workers norms, managers behaviour, as well as policy-makers thoughts” (Havas 2002, p.381).

An example of a new entity created at the interface of the domains sketched out by the triple helix model, one of these so called ‘hybrid organisations’ that possibly falls into Radosevic’s description of new pattern or mezzo level organiser, can be seen in Hungary. The National Chamber for Innovation is an association of technology intensive firms and research organisations who try to compensate for the lack of explicit government policy making by releasing policy statements and initiating reforms. The impact of these achievements may not be large, but their success may be better measured by the flow of market and technological information between participants (Balazs, 1999).

However, it is not merely the appearance of new actors that are an important demarcation of post transition innovation systems. It may be the mode of governance and the role of the state in influencing the transition of institutional arrangements that are the divisive factor. Referring back to the triple helix models of section 3.1, it was made clear that given the importance of the role of the academic sector in innovation, ‘triple helix model 3’ is the

idealised situation. What is fundamentally different between for example the American model and the Eastern European models is that they are or have attempted to reach the same goal from two different positions.

The American model of knowledge commercialisation did indeed originate from a linear innovation model with the 'entrepreneurial university' at its core. But it was an 'automatic laissez-faire process'. It was realised in the 1930s at MIT in New England by Karl Compton (President of MIT) that a more systematic support structure was required. Thus in the 1940s, an assisted model of innovation was created with the addition of a technology transfer and licensing office (effectively a search mechanism to identify potentially commercialisable knowledge) and also a venture capital firm to provide financial and organisational support for new start-ups (Etzkowitz, 2002). The transition is therefore from triple helix 2 to triple helix 3. A second important point is that the mode of governance to effect this change in the US is described as always having been indirect (Etzkowitz 2002).

In contrast, post transition countries have to move from triple helix 1 (the etatistic model) to triple helix 3. This involves not simply implementing new institutions and organisational structures where there were none before, but breaking and removing previous institutions and organisational structures before new ones can be implemented. This is arguably a much more difficult task taking into account the institutional lock-in and path-dependency mechanisms as discussed above. "We premise that the heritage of the etatistic model of the Triple Helix configurations in terms of university-industry-government relations during the communist regime, still has a significant effect on triple helix dynamics in transition economies" (Lengyel and Leydesdorff, 2007, p.3).

The role of government and policy in this change was also different to the American model. There may have indeed been the extensive rolling back of the state function as an over compensation for the many years of state control as written about in a general way for all CEE countries. And where there was a lack of state funding, government policy might have existed but may not have been actively implemented. However, in the Hungarian case, as will be discussed in chapter 5, there have been various S&T policies initiated by the government. The new priorities of S&T policy are expressed in public R&D contracts, reimbursable grants and so on. The new funding channels that have opened up are a reflection of the changing economic and institutional environment (Inzelt, 2004). To what extent have they been successful and actively restructured the institutional arrangements of the innovation system in agri-biotech, is an interesting question.

3.4. Conclusion to Chapter 3

In order to answer the central question of how context specific institutional factors effect innovative capabilities, there must be a theoretical framework to guide data collection and analysis. The demonstrable accumulation of scientific expertise and competencies, the trajectory and evolution of science in the Hungarian system shaped by internal and external forces, draws us towards evolutionary economics in the search for a suitable framework.

Amongst this vast literature the National Innovation Systems approach stands out as being particularly appropriate due to its focus on three main areas. Firstly the importance of the national context is emphasised to include national public policy, the structure of national

production systems and the limits of transmission of tacit knowledge. Secondly, the approach considers innovation as a cumulative systemic process which involves learning. Thirdly actors are placed within a system which comprises a network of institutions. The nature of institutions importantly are defined as sets of common habits, routines, established practices, rules or laws that regulate the interactions between actors.

In parallel this work also considers the Triple Helix model which unlike the NIS approach, does not assume that firms are the leading actors in the innovation process. Innovation is instead influenced by the arrangement between academia, industry and the state. It therefore may be argued that it is more suitable tool for analysis in the Eastern European context given the greater role of the public sector. Using a triple helix framework also allows a more specific analysis of the interactions of actors at the interface between academia, government and industry and those which cross the interface e.g. boundary actors. The quality of the institution is also emphasized uniquely by the triple helix framework as one of the determining factors in the innovation system.

These two areas of literature together aim to analyse and sketch a picture of the innovation system and its actors. Creating a picture of the innovation system, the actors and their roles for the innovation system in Hungary for this particular sector will be an important part of the thesis since a current picture does not exist. However, more than that, the thesis aims to investigate the question of how the quality of the institutional framework effects the activities, the flow of knowledge, the behaviour of actors, and other factors of innovative capability. Given the definition of institutions established in this chapter as rules, norms,

codes of behavior that determine the division of labour and knowledge flow, the thesis will later demonstrate the following important qualities of the institutional framework:

- Divisions of labour in basic and applied research as shaped by path dependency.
- Institutions that allow and are shaped by a particular culture of learning and trends in molecularisation.
- The ability to form new connections and the establishing of new institutions between new actors and so allow for system adaptation.

Studies of the effects of the institutional framework on innovative capability have been performed in the context of other global regions but relatively few have been done in the Eastern European context with the theorized features as described above. Fewer have examined biotechnology as a specific sector. Those few which consider the biotechnology sector in Hungary that have been done, are described in chapter 1. There are however still gaps which these literatures do not cover. Firstly, there has been only one qualitative study which examines in detail the institutions of the innovation system. The study by Rafols (2006) is a quantitative survey and draws a descriptive picture. The study by Bross et al (1998) is qualitative, but used data collected in 1995/6. And so secondly, a current and up-to-date picture of the situation after accession is missing and with regards to crop biotechnology, taking into account the de facto moratorium.

The literature reviewed in this chapter does not adequately address the problem of market demand for innovation. In some ways this is not a gap that has to be filled by this study. The peculiarity of the situation means that there is no effective demand for GM products nationally. Internationally there may be some demand for innovative services or products

and it will be within the remit of this project to examine how the key innovative actors respond.

Chapter 4: Methodology

4.1. Introduction

After a brief review of the history of biotechnology in Hungary and the most relevant and recent work on the subject in chapter 2, chapter 3 examined in detail the theoretical literature. Selected theory brought forward the concepts of national innovation systems, the triple helix structure of relationships between academia, industry and government and the more general idea of institutions which links both theories but highlights a difference between them. Elaborating on these concepts as was done in the previous chapter, assists in understanding the research question and exactly what is required to answer it. It goes some way towards operationalising the larger overarching concepts of ‘innovative capability’ and ‘context specific institutional factors’ as specified in the research question. The aim of this chapter is to operationalise the concepts more completely and to formulate a method which allows the collection of the most appropriate data to answer the question posed; how do context specific institutional factors effect innovative capabilities?

This chapter on methods used, is structured as follows: firstly the overall research strategy will be discussed with a review of the choice of country and a brief description of the study design. Next, the operationalisation of the concepts described in chapter 3 are further elaborated. This points us to a qualitative rather than quantitative study, and the draw backs and benefits to both are discussed. Section 4.5 then makes the argument that despite the seeming suitability of the case study approach, this study actually cannot form a boundaried ‘case’. The study instead is an investigation and analysis of a system. After addressing the

problems associated with the general design, the latter half of the chapter moves on to describe the methods of data collection, the ethical considerations and the data analysis.

4.2. The Overall Research Strategy

This work has selected Hungary as its focus. As discussed in chapters 1 and 2, Hungary has a strong agricultural tradition and historically, is renowned for academic excellence in the field of natural science. Generally though, the extent and form of agricultural biotechnology is largely unknown. The work so far reviewed (see chapter 2), in particular that done by Bross et al (1998), Tzotzos and Skyrabin (2000) and Rafols (2006) alongside recent applications for field trials, indicate some research activity in this area. These more historical accounts and survey type studies, may give only an impression of what may or may not lie beneath the surface and current output due to the regulatory context (see chapter 2) may not be a true reflection of underlying innovative potential or capability.

Since the agricultural crop biotechnology sector has not been investigated since 2000, it falls within the remit of this study to uncover the parameters of the system and broadly sketch its extent, actors and activities. There is a lack of a sample frame on which a survey can be based since actors (and especially small and medium enterprises) enter and exit the system very quickly possibly due to economic difficulties. Partly for this reason, we opt for a qualitative approach.

The research question asks how context specific institutional factors effect innovative capabilities. The sub research questions break this down into questions on the evolution of

the network of actors and the characteristics of the technology, the sustained use of institutional arrangements in this network, and the difficulty of this network in adapting to the current regulatory environment (see Chapter 1, overview).

To fully answer the research question this study requires an understanding of the historical and current political context surrounding the science and technology system and an understanding of ‘institutions’ which are tacit and difficult to measure. It is not appropriate to undertake a survey-type investigation such as that exemplified by Rafols (2006, see Chapter 2) which rather draws a descriptive picture of the innovation system rather than investigating the mechanisms behind innovation, knowledge transmission etc. However, an in depth investigation of an innovation system, its actors, their roles and the influence of the institutional framework, requires substantial resources. This study is therefore restricted to a single sector rather than being a cross country comparison involving two or more countries. This necessarily raises the question of generalisability and what can be gained from the study of a single ‘case’. This question will be addressed in section 4.5.1. on the subject of the case study later in this chapter.

4.3. Operationalisation of Concepts

The research question centres around the idea of investigating the influence of one set of institutions upon another. The question asks: how do context specific institutional factors effect innovative capability? One set of institutions are formal rules imposed by the wider context and includes the regulatory framework for GM crops imposed by the EU, national science and technology policy and the national regulatory framework which prevents GM

crop commercialisation. The second set of institutions are those which belong to the national innovation system and are more difficult to define. These would be the common habits, routines, established practices, and so on as theorised in the previous chapter by authors such as Edquist and Johnson (1997).

The first set of formal context specific institutions are fairly simple to identify. It is not their formation or the policy making process which is of concern in this study. I take for granted their existence and instead look for how they influence the second set of institutions. For example, I look for how the regulations are perceived by the key innovators of the system and to what extent they influence the day to day activities of innovative actors.

In searching for answers to these questions, and before understanding how regulation and legislation impacts upon the institutions of the innovation system, it is important to understand the mechanics of how the innovation system works in terms of institutions and how innovative capability can be found and assessed in a system which is prevented from creating an output in the form of a GM crop. In using the term ‘innovative capability’ rather than ‘innovation’, the object of the study is redefined. Since there cannot be a commercialised GM crop output, the study will identify those practices and outputs which contribute to the ability of innovative actors to survive, develop within their field and retain the possibility to re-engage in the system should the context change and the opportunity to develop GM crops become a reality. Innovative capability in biotechnology is something more tacit and is likely to reside in networks as well as being an attribute of particular individuals or organisations. Indicators of innovative capability which will be investigated

are: the formation of new organisations, the formation of boundary organisations (see chapter 3), the formation and utilization of networks and network connections, the information dissemination strategies of actors and other activities which at this point will be defined as those which conserve innovative potential or use scientific knowledge.

The institutions that have been described in chapter 3, are built into such day to day activities of actors and so this study will look at these networking, dissemination, scientific practices and outputs in order to find used and shared routines of communication, how learning is transmitted, how activities change in response to the wider context specific institutions and how adaptation occurs. These interactions will be vast and clearly it is not possible to record every such action. And so the study will focus on key innovative actors, the reasons for which will be covered in a later section of this chapter.

Innovative capability and the capability to survive, develop and re-engage is challenged by the inability to adapt. A further way of narrowing the field of observed interactions is to look for those institutions help or hinder adaptation. As defined by chapter 3, these institutions are the products of institutional lock-in, trajectory, rigidity or path dependency. Thus the main research question is elaborated into three further sub-questions for purposes of better operationalisation and to take into account institutions that challenge or are challenged in this way. The sub- questions are as follows: Has the network of actors in the innovative agri-biotech sector evolved in a way that accommodates the peculiar characteristics of the technology? Do linkages between actors in the network demonstrate the sustained use of institutional arrangements which characterised the pre-transition NIS? Does this existing network as it has evolved, show difficulty in adapting to the regulatory

environment created in the country's post accession phase? Although the answers to these questions were theorised in the previous chapter, the case with regards to this very particular sector and country is not known.

To summarise; operationalising the institutions that contribute to innovative capability was done throughout the data collection period in a grounded way. The data collection strategy looked for institutions (connections, relationships between the actors, rules, norms and codes of behavior) that add to, or detract from innovative capability. Institutions defined in this way that were observed were those that denoted divisions in labour such as regulations, or behaviours that instructed some actors rather than others to teach or conduct research. They were those that were shaped by learning and culture, for example the establishment of particular behaviours that allowed laboratory based hands on learning. And they were those that demonstrated the ability to form new connections between the actors allowing for system adaptation, such as the formation of contacts between research and flow of information with scientists outside, but brought inside the system. Innovative capability also had to be operationalised throughout the data collection period in a grounded way. The way this was done was to look at the primary actors and observe behaviours that allow the knowledge and skills that contribute to innovative capability to endure and perpetuate in the system over time. Such behaviours included the publishing of papers, learning of skills and techniques and the maintenance or creation of connections and information flows with other actors. This type of data gathering was done by observing and questioning the actors on the institutions created, used and engaged with and from this, infer what effect this has on innovative capability i.e. the knowledge and skills that contribute (or have the potential to contribute) to innovation and their ability to endure and perpetuate over time.

4.4. Qualitative and Quantitative Methods

The operationalisation of the concepts above, strongly suggest that a qualitative methodology is best suited to form an answer to the research question. Institutions are a somewhat 'fuzzy' concept. They are difficult to measure and define by statistical means. The impact upon them is even more difficult to quantify and will best be found indirectly. A change in output, direction or trajectory for example will show adaptation and information along these lines can be more easily found by interviewing key people rather than surveying a number of institutions. Without a greater familiarity of the nature of the innovation system, the extent and form of output and the actors involved, the study lacks the ability to form at the outset, quantitative indicators or a sampling frame which would be the basis of a survey or statistical analysis. Alternatives to a qualitative analysis include surveys and sampling techniques to assess the actors in the system, the nature and quantity of the output. Such statistical methods certainly quantify aspects of the system but can give little direct indication as to why certain trajectories are pursued in a scientific system or why particular strategies are employed to adapt to legislation. These questions require data from either spoken or textual sources that have the competence to explain as well as describe. The use of indicators would be a partial solution to this criticism. A series of indicators or indicative questions might be correlated to an explanatory variable. However a compilation of statistical indicators assuming a measurement of, for example; actor networks or innovative potential, requires a certain amount of speculation and assumption. Focusing too narrowly too early by use of assumed indicators, on an ill defined subject carries with it a risk of missing crucial features of a larger picture.

Biotechnology as a sector covers animal biotech, medical and human biotech, pharmaceuticals and plant biotech. In light of the recent moratorium and the trend away from the plant sciences (interview data), plant biotechnology is likely to be a small proportion any compiled figures. Figures for plant biotechnology sector alone do not exist and any qualitative indicators that do exist do not reflect innovation and the knowledge production that contributes to innovative capability. A part solution to this problem would be to perform a statistical summary of the literature and articles produced by Hungarian plant biotechnologists and scientists. This poses problems such as the requirement to survey journals produced in the Hungarian language and counting not only single authored papers but those produced jointly by Hungarians and those working in multinational teams. These problems are solvable but a bigger problem exists in that while knowledge is a significant component of innovative capability, I do not wish, at the outset of this grounded piece of work, to define innovative capability solely in these terms. A quantification of publications is only useful if it can be compared to other countries with due regard to the size of the sector and population, or to examine the publication trend over time. This undertaking would involve creating a significant quantitative component to this project and would detract from the goal of defining innovative potential through a more qualitative grounded approach.

Those advocating statistical techniques would champion their ability to demonstrate rigour in scientific approach, to allow generalisability through the careful sampling of cases and the measurement of real observable data which runs no risk of “being dismissed as metaphysical” (Hammersley and Atkinson, 1995 p.4). In contrast the techniques which are necessarily employed in this study, may be seen as constructing theories and conclusions

from the data which are subjective and open to interpretation. There might be some attempt to limit the possibility of researcher bias perhaps by building into the research design, methods of triangulation (see below), and also in answer, there is some advantage of not facing the research question with pre-constructed hypotheses. Perhaps though this is inescapable and the only answer is to approach data interpretation with a degree of reflexivity, accepting that interpretation is shaped by the literature read (and a number of other factors), and noting any preconceptions as they surface. The problem of researcher bias is framed by Yin (2003) as that of reliability. The ability for another researcher to arrive at the same conclusions through doing the same study is a central tenet of research design. Countering bias and demonstrating reliability is achieved by extensive documentation throughout the research process.

4.5. Beyond the Case Study Approach

A rushed presumption would be that the research question would be answered well with a case study approach. Yin's introductory description of what a case study involves seems to fit well with the goals of this study. Case studies are appropriate for answering the 'how' and 'why' questions in social research. Questions which ask 'what' or 'how many' might be addressed with a survey, and clearly this study requires more. Therefore the case study according to Yin is useful not only as an initial exploratory tool in research but also has the power to be explanatory and descriptive. Case studies do not have to involve comparisons between multiple cases, but can exist as single-case studies. Case studies are suited to a context where the researcher does not have control over behavioural events, where experiment and control over variables is not possible. And finally case studies do not

always take units of analysis where the boundaries are clear. Yin states “A case study is an empirical enquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 2003, p.13). Thus ‘cases’ can include studies of decisions, individuals, organisations, processes, programs, neighbourhoods, institutions and events (Yin, 2003). From Robson (1993) we can add that through its recognised flexibility in accommodating multiple methods, the case study method is worth considering.

In practice amongst the first uses of the case study was the work undertaken by members of The Chicago School in the 1920s and 30s. Researchers from this school examined the relationship between crime, poverty and the urban environment. Conclusions from this work often point to behaviour being a product of environmental, physical and social factors with the city functioning as a ‘microcosm’. In response to the Chicago school Burawoy puts forward an alternative extended case study approach. Burawoy’s critique suggests that the specificity of each situation is repressed and in the aim to find universals which underlie all social situations via single studies that are so particular and in depth, the connection to a wider context is lost. In contrast Burawoy examines the work of Gluckman and the evolution of the interpretative case method. Here a study of a South African microcosm, a single event, reflected the wider social structure. The interpretive case study is thus concerned with the way the macro is present or expressed in the micro. Gluckmans successors however began to look at how this social micro situation was *shaped by* macro forces. This is the essence of the extended case study method which “looks for specific macro determination in the micro world” (Burawoy, 1991 p.279). In its aim the extended case study method constructs what Burawoy terms “genetic” rather than “generic”

explanations of particular outcomes. Genetic in these terms refers not to molecular biology of course, but is a metaphor for focusing on the differences due to a historically specific causality rather than forming a generalisation from observed outcomes – i.e. a ‘generic’ explanation. In doing so there is a general objective to reconstruct existing theory.

4.5.1 Generalising From a Single Case

These two approaches raise an interesting question for this study. Is the aim to form a generalised theory about institutions and innovation, to find a ‘genetic’ explanation (as referred to by Burawoy 1991, p.279) that would be true for the macro as well as the microcosm of the Hungarian agri-biotech innovation system? Or is the objective of the study to examine Hungary as a unique case where institutions and actor behaviour are reflective of the particular institutional environment?

This study aims to produce generalisable conclusions in order to be useful and perhaps to inform policy making. While the background chapter showed Hungary to have many unique features, it is the combination of these features which make the country unique, rather than each feature existing in global isolation. For example, the transition context from communism to a free market has occurred in a specific way in Eastern Europe, yet many countries will face the economic difficulties that have been described. Lysenkoism and its avoidance only occurred in Hungary, but many other countries will have the same resulting capacity or potential for innovation due to a completely different ‘story’. The study will look at the national innovation system and its ability to adapt its institutions to

stress and change. These are universal concepts and therein lies the capability for this work to be generalisable.

So in answer to the question posed above, the study leans more towards Burawoy's extended case study approach in its efforts to create generalisations, a genetic explanation that is true of the macro as well as the micro, rather than examining the microcosm as a the determining factor.

However, in this study there never truly exists a 'microcosm'. The study draws together different levels, which make it a system rather than a case. In addition to the innovation system responding to national legislation, it must also respond to European legislation and the globalised context. As discussed in chapter 3, the innovation systems in practice are likely to overspill national boundaries.

Considering this as a system with multiple levels, with institutions extending further than the borders of a country and further back in history than the present, clearly presents difficulties in defining the 'case'. The conventional answer to the question of what defines a case is given by Ragin and Becker: "boundaries around places and time periods define cases" (Ragin and Becker, 1992, p5). This study therefore surpasses the case study method and should be instead described as an investigation of a system. In order to examine the system, I undertook a series of investigations, employing a number of different strategies and these are described later in the chapter.

4.5.2 Other Criticisms

At this point, having addressed the criticism of generalisability, it would be well to address other points of criticism. These will be common to the case study approach since the system investigation method employed here is apparently similar up until the point at which I ask what defines the case.

Case studies have in the past been criticised for a lack of rigour. This might also be viewed as a problem of demonstrating internal validity. Theories formulated or causal explanations should be compared and tested against rival explanations to show that the internal ‘logic’ of the research design is correct and the evidence converges towards reliable conclusions (Yin 2003). This is difficult to incorporate into a study of a system where there is a high degree of interdependency, connectedness and contributing influential factors, as there is in a national innovation system. The strategies that are employed to counter any possible lack of rigour involve thorough documentation which underlie all data collection and analysis. The study also relies on triangulation through varying data sources and emerging causal explanations can be cross checked with informants (further detailed below).

The nature of the study, in that it is a qualitative piece of work undertaken during a specific period and by a particular researcher have so much to do with the data that was revealed and collected. This challenges what Yin (2003) would call ‘reliability’. The particular style of interview, those available for interview and what they revealed during each interview are highly specific to the time and context and it therefore unlikely that another researcher would be able to duplicate the research exactly. While it is not repeatable it most certainly

is testable. Another such similar study would demonstrate the same use and manipulation of institutions, the same trends in science, the same learning and behavioural patterns and so on, because these change very little over short periods of time and there is a cumulative learning effect. Therein lies the ability of the study to show reliability.

4.6 Data Collection Strategy

A reasonably detailed study of the various system components will require more than one single method of data collection. In the same way that the case study approach uses flexibility in its data collection (Robson, 1993), so may this type of system analysis. A case study may exist anywhere between the two extremes of looseness and selectivity, or exploratory and confirmatory, according to time constraints. We may suppose that these different positions can be adopted also in order to develop inductive or deductive hypotheses or conclusions from the data. As this study progresses it can be expected that from an initial exploratory style, the case study would gradually become more confirmatory and data collection will become increasingly selective.

This study features the extensive use of semi structured interviews and additionally benefits from observational data. 27 formal interviews were undertaken (See Appendix B), a number of unrecorded informal conversations and a number of sites were visited. Interviews were mostly single rather than multiple. Two scientific conferences were attended and observations from these activities will supplement the data. Field work was undertaken in two stages; in autumn 2006 and spring 2007, allowing a reflective period in between for a partial analysis of the data.

Field work also involved the gathering of a substantial amount of secondary data. Secondary data took the form of press and media articles, company and organisation reports and publicity material both in paper format and sourced from the internet. These were collected over the 2006-07 period. The material was used not only to inform the interview process but also contributes in a major way to chapter 5 where the innovative network, in terms of actors and activities is described in detail.

4.6.1 Key Informants

Scientists in Hungary are the key actors in the field of agricultural biotechnology. They are therefore viewed as the key informants in this project. Approximately half the interviews are detailed conversations with the key scientific personnel in the field. Questions pertained very much to their activities though time, their ideas on the future of the science in their country, the factors which are crucial to their success and how they view national and international regulation and legislation. Their lens on the world and their view of regulation is an essential part of how the regulatory structure impacts on innovation. It is not necessary to study the legislation as grey literature or as a focus itself, since what matters is its effects on the key innovative actors and the institutional environment it creates. As interviews progressed a number of key factors were freely identified by interviewees and these were made special reference to by the interviewer in successive interviews to ensure that evidence converged and triangulation of data was achieved. Interviews throughout had to be simultaneously open enough for the interviewees to introduce new concepts that they felt were important but perhaps not previously identified. Semi structured interviews as

opposed to structured or open interviews are ideally suited to collect this type of data. The key innovators in a small country with a limited range of activities are not difficult to identify. Publication searches, reputations and the conferences attended are factors that assisted in the identification process. Informal conversations with conference attendees were confirmatory. A summary of the interviews undertaken is given in table 2. A full listing of the interviews is given in Appendix B

Table 2: Summary table of interviews undertaken 2006-2007

Total number of interviews	29
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Type of interview	
Recorded formal	25
Unrecorded anonymous	2
Unrecorded informal conversations	2

Type of interviewee	
Scientists	13
PhD students	5
Social scientists	7
Companies	4
Policy informers/officials	4

Location of interview	
Budapest	20
Godollo	5
Martonvasar	2
Szeged	2

A key part of biotechnology innovation systems and innovation potential is application and the possibility of taking through research to further stages of production. This is highly

limited in Hungary but several key personnel from national and international biotechnology companies were also interviewed in order to gain as comprehensive a picture as possible.

A third important group interviewed were Hungarian academics in the field of science and technology studies. Although few of those interviewed had very specific knowledge of the biotechnology sector (and none on plant biotech in particular), their expertise and knowledge of the Hungarian economy, their views on the important factors in the regulatory environment and their familiarity with the evolution of innovation systems in Hungary through history were of vital importance in the triangulation of data. It might be assumed that further information possibly regarding the plant biotech sector may exist, but are published in Hungarian and so have not been accessed by the researcher. This possibility was explored through interviews with academics but did not attain any promising leads.

Several policy makers were also interviewed. However, the number of these are quite low and there is difficulty here in maintaining rigour through triangulating by comparing the responses of one informant with another.

Given that authors such as Pohlmann (2005) define innovation as “a product of the evolution of social systems” which cannot be directed or steered by a single actor or agency, how valid is it to examine the evolution of innovative potential without a detailed examination of the actors who lie outside the triple helix (Etzkowitz and Leydesdorff 2000) which is the focus of this project? Specifically we might mention NGO’s, the public and the media. The development of the science and technology system during the communist era

was detailed in chapter 2. Notably the science system developed in relatively isolated conditions. The state played a central role in its direction and arrangement. More recently in the post accession phase these actors have become more influential. The focus of this study is on how the inherited system as it has evolved, adapts to the new environment. The focus of the study is not on public perception, policy making or social shaping, which would require separate in-depth work to be conducted. This type of work is at the moment being conducted by Hungarian academics (for example Kasza 2008, forthcoming). This study in its initial stages found that these actors are now influencing policy and this is a potential shaping force since national policy is preventing certain outputs. For now it makes little difference if this study uses national policy as a source of change rather than investigating in detail the actors that might have caused the change in policy.

4.6.2 Practicalities of Data Collection

The field work visit was hosted by the Economics department of the Hungarian Academy of Sciences. The researcher was attached to this institution whilst undertaking data collection. This afforded the opportunity to present the project proposal and findings to personnel at the institution and experts in the field of Hungarian economics. This methodological cross-checking is perhaps worth noting. Association with this institution also facilitated gaining access to certain individuals and organisations.

Data collection was divided into two stages. An initial visit of 6 weeks in September - October 2006 and a second visit of 4 weeks in April 2007. There are certain advantages of designing the data collection phase as two distinct parts. The interim period was used to

begin the data analysis. Some conclusions were drawn and some causal relationships extracted and these were taken back to scientists and academic informers in the second stage to cross check and validate the emerging results.

An interview schedule was drafted for each interview. Interview schedules, as can be expected, changed substantially according to the interviewee, the organisation and the stage of data collection. As mentioned previously key emerging concepts were introduced (but not pressed) by the researcher as interviews progressed. The interview schedule noted the surroundings and the conditions under which the interviews took place. All interviews with one or two exceptions were digitally recorded for future transcription purposes.

The only language available to the researcher is English. It is suspected that other sources of data exist in the Hungarian language, but these were not found. The interview invitations were made in English in most cases but also occasionally in Hungarian with the aid of a Hungarian speaker. Where particular interviewees such as policy makers were targeted translation services were offered. However it may have been the case that only those who spoke English responded to letters and written requests for interviews. There might therefore be a bias in the data. The overall conclusions and results of analyses were checked by presenting significant sections to an audience of Hungarian scholars at CEU University, Budapest, and did not result in any anomalies based on a difference of opinion or questioning of the data or the results.

The style of interview possibly assisted in gaining information. It was conversational, exploratory and did not challenge the interviewee or their assumptions. The objective was

to gain an accurate picture of their perceptions and their real opinions on the matter of EU and national policy and to find out about their role in the innovation system.

4.7. Ethical Considerations

The ethical aspects of this project are relatively few. The study does not involve participation of vulnerable informants nor does it impact on any vulnerable groups. The research design is open and there is no requirement for keeping confidential the identity or intentions of the researcher. It is assumed that the identity of the researcher did not significantly influence the interview responses. However, such assumptions need to be treated with care as it is entirely possible that the introduction of the researcher as a student may have led interviewee's to be more or less open than they might otherwise have been. The ethnic background of the researcher may have also had some impact on the information gained, though this was if not positive, hardly perceptible. It is not thought that the gender of the interviewer or interviewee's had any impact on the interview process.

The conduct of interviews followed the principles of fully informed consent. Interviewees were informed at first contact, the purpose of the study, the personal interests of the researcher, the use of recording equipment and their rights not to participate in the study, to remain anonymous and to withdraw consent at any time. Where the interviewee requested, recording devices were turned off and an agreement as to how the researcher would use 'off the record' information was reached. Interviewees largely wished to see the transcripts before signing a consent form agreeing the extent of their anonymity and whether they agree to its release. Consent forms accompanying a written transcript of the usable sections

of interview material were posted and consent granted after the interviews and before the submission of this thesis. The availability of the consent form in Hungarian was also made known to participants. The possible use of the published material in the form of papers and presentation material was made known to all participants and participants were granted the right to see the relevant pages of the thesis to ensure they had not been mis-represented. Participants were informed of these rights before the interviews were conducted.

Data has been kept secure and access given only to the supervision team and the researcher.

4.8. Data Analysis

Analysis occurs after transcription of interviews into a written form followed by coding the text into concepts. There is initially a relatively open approach to the coding and data analysis. The first objective is to further add to the operationalisation of concepts such as innovative potential and also to quantify and describe the parameters of the system in terms of output and actors.

Information from the key innovators of the system is the first to be coded in this manner. Interviews were individually coded using the Decision Explorer software using concepts taken directly from the interview text. Any text in an interview transcript that may be described as a key word, phrase or concept was highlighted and coded using that word or a shortened form of the phrase or concepts. These fairly openly coded concepts are termed ‘level 0’ concepts. Level 0 concepts represent the text at ‘face value’. Very little interpretation is done at this stage and so the concepts represented the perception of the

interviewee. Each interview typically outlined between 50 and 90 level 0 concepts. Interviews were presented in the form of 'concept maps' which had the advantage of including all information given in a single interview and preserving the relationships posed by the interviewee. Essentially the concept map was a diagrammatic representation of a single interview. Concept mapping in this form closely resembles coding. The main advantage is that relationships between concepts and the way they are referred to by the interviewee, are preserved. There is no deconstruction and reconstruction of the interview transcripts to form groups and then to afterwards infer causal relationships as there is in open coding and grouping. Therefore the complex relationship between innovative capabilities and institutions are preserved. The contributing behaviours, rules and norms which make up the institutions in question e.g. national regulation, writing, learning, publishing, communicating, in all forms and descriptions, can be drawn and made to connect to all the defined aspects of innovative capability – the maintenance of connections, the creation of knowledge and the ability to pass on that knowledge, again in various forms. There is no limit as to how many lines can be drawn from one concept linking it to others and each relationship in terms of how one affects the other can be preserved as unique without making generalizations at too early a stage. Each map can then be compared to others in order to form those generalizations as described below. An example is given in Appendix D. The numbering of each concept refers to the progression of the interview and when each concept was referred to by the interviewee. There were a number of implicit and explicit relationships occurring between concepts in a single interview and these were also mapped. Single lines indicated a non specific relationship where two concepts are related in a non-consequential way, whereas arrows indicate a causal relationship. This method of mapping an interview and forming concepts borrows

ideas from cognitive mapping but is essentially different in several ways. Notably in cognitive mapping the concepts are rearranged into a hierarchical order, illustrating which concepts are prioritised by the interviewee above others. This is more problematic with semi-structured interviews where the concepts were sometimes introduced by the interviewer. The interview becomes a more ‘artificial’ setting with the areas of interest and priority under discussion, being manipulated and dictated according to the interest of the interviewer and not just the interviewee. In this type of ‘concept map’ the maps therefore take no structural form, with numbered concepts following the progression of the interview.

Concept maps were then brought together and a smaller inclusive list of approximately 20 – 25 concepts were formed. These ‘level 1’ concepts are formed by the researcher and include a much greater amount of subjective interpretation and influence from literature study. The formation of level 1 concepts was an attempt to pull together and categorise level 0 concepts. With a number of level 0 concepts classified under a more general concept heading (level 1), this more general concept could be elaborated with meanings and relationships stemming from its contributing level 0 concepts. Level 1 concepts were tabulated with all corresponding level 0 concepts in the next column to ensure that all level 0 concepts had been taken into account (See Appendix C). If a level 0 concept did not fall under the heading of any existing level 1 concept as an explanatory, causal or consequential concept, it became a new level 1 concept. At the end of this tabulation exercise, level 1 concepts which had few attributing level 0 concepts and which were not well linked to others, were dropped from the main analysis. In Appendix C this was the case with such level 1 concepts as ‘the use of IT’ and ‘the competitive market’.

From the tabulated list that was eventually developed and constant referring back to the interview concept maps, an amalgamated concept map was drawn which illustrated as 'hubs' the main level 1 concepts and as 'spokes' the level 0 concepts as causal factors, descriptives, consequential events, etc. Some level 0 concepts due to cross referencing actually became hubs. The amalgamated mapping exercise ensures that no key concepts are lost. The hubs, which centered around level 1 concepts such as 'networks' eventually created the main points for analysis in chapters 5, 6 and 7.

Relationships between all concepts and contradictory evidence were preserved with this method. This system while being inclusive and rigorous, due to the preservation of relationships and all concepts, is not in danger of losing the meaning of the text through intensive open coding (a common criticism in ethnographic data analysis). Nor is there a great possibility of coming to premature or false conclusions by dropping disconfirming data or directly coding into level 1 which might reflect researcher bias (Eisenhardt, 1989).

The remaining data from academics, policy makers, the private sector and observational data were coded using the well developed level 1 concepts. This remaining coding was done by hand using only word-processing software. From these amalgamated maps and coded information the relationships between contributory factors are clearly seen and conclusions were drawn. The mapping exercise is not elaborated further in this thesis because at this early stage of creating the amalgamated map and comparing with the individual interview maps, a lengthy written description of each level 1 concept was created and how each level 0 concept contributes to its formation and complexity. This rich description of each major concept and its associated relationships with other concepts and

with references to the interviews from which they arose, becomes the backbone of each of the empirical data chapters. The amalgamated map is simply too large to include and individual interview maps cannot be included due to the need to preserve anonymity.

Triangulation occurs by comparing responses between and within the different groups of actors. Predictive validity in the extended case methodology is easily demonstrated and the same can be said here. Many of the relationships will demonstrate at a micro level the effects of macro processes (e.g. economic conditions and national policy). If the results and the relationships indicated are the reverse of what is essentially at the broad macro level, common sense or logical causal effects, the data and underlying assumptions will have to be re-examined.

The process reflects a compromise between the inductive and deductive approaches. Initial coding contributes to the operationalisation of the main concepts or as Eisenhardt (1989) puts it, sharpening of the constructs. Secondary coding is directed partly by the research question and the literature and partly by the emphasis placed by the initial codes.

4.9. Conclusion to Chapter 4

From this chapter, various methodological problems have emerged. First, the thesis must consider how best to operationalise the concepts of innovative capability. This was partially achieved in the previous chapter by drawing on the theoretical work of other authors and definitions of an innovation system and what factors and actors are required for the system to function effectively. However, inherent in all models of innovation is the notion of

‘institution’. Since institutions are highly context specific and are a product of the social evolution of the system, the precise units of analysis are not provided by the literature. The full operationalisation of the concepts will be achieved by constant reflection and analysis of the data throughout the data collection period.

The necessity to complete operationalisation during data collection analysis means that certain methods are more useful than others. We disqualify the quantitative methodology for example, on these grounds and instead opt for semi-structured interviews and observational data alongside a method of data analysis that is loosely based on grounded theory (Glaser and Strauss, 1967).

Secondly, there is a problem of not being able to frame the research as a single ‘case’. It is not neatly boundaried and has several levels of actors. There is the problematic question of how a ‘system’ can be analysed. We therefore draw out two of these levels: the regulatory framework, and the key innovative actors with the aim of studying the effect of one institutional level upon another. In the effort to narrow the scope of examination in the system, we exclude certain other actors such as the public, NGOs and so on. This also creates a question: how legitimate is it to provide an analysis of a system without considering the input and influence of certain of these actors? In some ways the Hungarian context (the assumption that the will of these actors are being reflected in public policy on GM) circumvents the need to study them in detail. But still, by ignoring parts of the system only further pushes this investigation away from its ideal of being a neatly enclosed ‘case’ - an entire system. And perhaps this is the defining point at an analytical level which

prevents a 'system analysis' being the same as a 'case': the selection of various institutions and levels, rather than the whole in order to study the effects.

The third and last of the more significant methodological problems is the question of generalisability and what may be learned from this seemingly unique analysis. The Hungarian situation may be seen as quite unique. However, generalisations can still be made by investigating concepts which are universal and common to all systems. For example, the ability of institutions to adapt. This is something which innovative potential and capability depend on, in any innovation system.

Chapter 5: The Main Actors and a Disjointed System

5.1. Introduction

Chapter 4 outlined the research strategy, methods of data collection and analysis that were used. This chapter is the first of three data chapters that will present and analyse the data collected. Data in this chapter is sourced from observations, various interviews as well as from secondary data in the form of press and media articles, company and organisation reports and publicity material both in paper format and from the internet. These were collected over the 2006-07 period.

The aim of this chapter is to outline the structure of the innovation system and the parameters of the investigation. The main innovative actors are introduced and descriptions of their role and activities are given. This is important firstly because it is new data. Up to this point there has not been an up-to date substantial description of the innovation system in this particular sector. In accomplishing this task, this chapter contributes to answering sub-question 2 on the sustained use of institutional arrangements that characterised the pre-transition NIS. These arrangements are demonstrated in organisations such as the Hungarian Academy of Sciences and the core group of actors in the centre of the science system. Secondly the chapter sets up an important framework and background for the next two data chapters which examine and analyse the institutions and factors that contribute to innovative potential. As previously discussed, in answering the research question of how context specific institutional factors influence innovation in this sector, the project will examine two institutional levels. The second tacit level of institutions which are responsible

for innovative capability complete their operationalisation in the next two chapters, but the first institutional level and the character of the state as an actor may be given here.

The first section outlines the overall picture and illustrates the four main categories of actors. The following sections then detail these categories by description of the organisations and their activities. The penultimate section looks at the regulatory framework within which these actors operate.

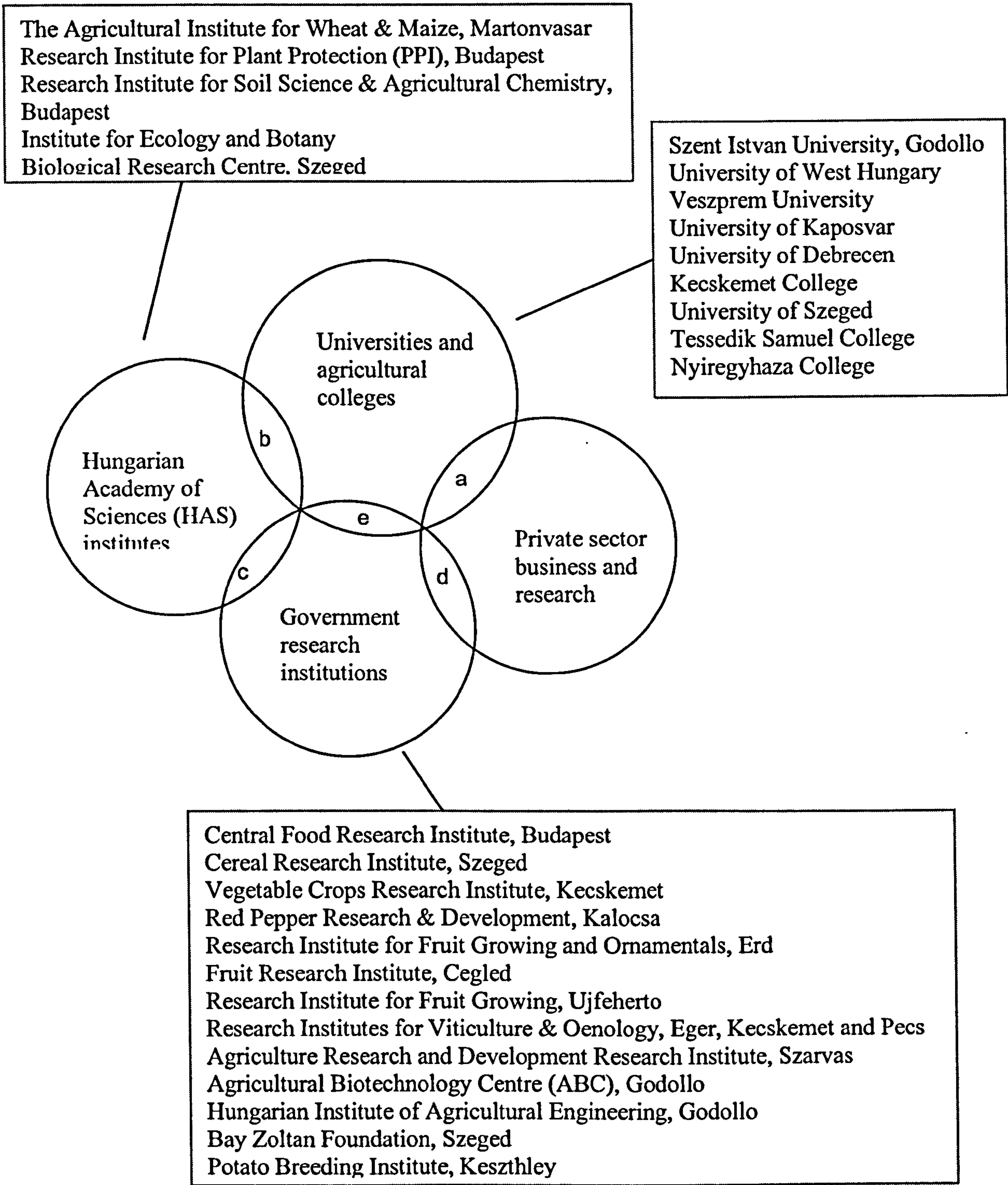
5.2. The Overall Picture of the Innovation System

The Hungarian innovation system in agricultural biotechnology depends on the contribution of a number of different individuals and organisations. These actors are involved with innovation to varying degrees and participate at different stages. The research and development institutions can be categorised into four as illustrated in figure 5.

5.3. The Hungarian Academy of Sciences

The HAS was established by Istvan Szechenyi in 1827. It began as a scholarly society dedicated not only to the natural sciences but also the social sciences, arts and humanities, providing grants, awards and creating the opportunities for meetings. The academy now belongs to the parliament and funding comes directly from the Ministry of Finance. The proletarian dictatorship established by the revolution of 1918 – 1919 wanted to dissolve the HAS, though after the four month dictatorship, it was able to resume work.

Fig 5 The Actors Involved in Hungarian Crop Agricultural Biotechnology



Throughout its history, successive governments have tried to use the academy to extend their social-cultural influence¹⁸. It was however, always considered to be an independent institution despite undergoing gradual reorganisation and transformation over time. The main forum of the academy was a general assembly (GA) for academicians held once a year. The assembly would elect a president, a vice president, a committee and other members on the basis of their scientific achievements. The GA presided over a network of research institutions, each institution being headed by an HAS academician. The institutes were established according to the principles of the linear technological development model and concentrated exclusively on basic research. The institutes were able to attract the best researchers in the country, seriously weakening research capabilities in higher education. Academic members were associated with considerable social prestige though the benefits were less important in Hungary than in the Soviet Union. Currently elections to be a correspondent member of the academy are held every third year. Later, if their publication record and progress is maintained, a scientist may be elected as a full member. It appears that academy membership is still regarded in many quarters as the ultimate goal in the career path of a Hungarian scientist.

Under the communist system 'scientific socialism' gave ideological priority to science. The previous generation of 'bourgeois' scientists were allowed to remain in their positions for some time before gradually being replaced by active party members. After the Second World War more dramatic restructuring took place with natural and technical sciences gaining significance. The institutes received government funding according to the number of employees and so the only way to increase funding was to grow in size. Poor quality

¹⁸ <http://www.mta.hu/index.php?id=674>

staff were not dropped and furthermore no real evaluation of the research outcomes were undertaken (Balazs, 1995).

In the early 60s the question of whether to introduce applied science arose but was opposed by the majority of members. It remained a controversial question throughout the 70s as part of the wider debate on what the role of the HAS should be. In these times state funding saw drastic cut backs and according to Balazs (1995) applied research was undertaken in many institutes anyway. Researchers were turning to additional contract work in order to make up the short fall in research funding. The important question is whether these links could create effective links between academia and industry. According to the literature, this was not the case:

“On the contrary it was simply a symptom of the gap between the research sector and firms. The idea of passing research results from the academic research institutes to the branch or industrial research centers never worked well in practice. Application or industrial implementation are the professional interest of the researcher and it was natural for East European researchers to follow up fundamental scientific results. The researchers gave up trying to transfer their results and started more and more to develop products in house, while at the same time picking up contracts relating to specific technical problems of industry. ...Academy results were not presented and developed in a way that firms could implement – which gave the firms a convenient excuse for inactivity.” (Balazs, 1995)

Transition would have exacerbated the initial problems of inefficiency and excessive size. Government funding fell further and the shrinking of the public and private industrial

sectors neither supplied the additional contract work nor the impetus for market derived solutions. The internal market created by the ex-Soviet states had also collapsed. In this new environment there may have been two options for survival: to search for an active approach and develop new mechanisms for adjustment; or to adopt a defensive strategy. The HAS, similar to other academies, opted for the latter (ibid). (Of course there exists the counter argument that before transition, government organisations were over inflated and transition and cut backs returned organisations to a more appropriate size (interview data, 2006).

This study is important for two reasons. Firstly, it examines the time since the transition. During the economic crisis, research and development were low on the governments list of priorities. The HAS and its strategy evolved in a policy vacuum. The policy landscape has changed somewhat and the effects of this new environment can be described. Secondly, rather than taking a view of the academy as a whole, it is possible to put under the lens, specific biotech units within the academy and in a much more micro-way, look at the activities and directions of the laboratories in question. This project involved interviews at two major HAS institutes: The Agricultural Institute for Wheat & Maize in Martonvasar and the Plant Protection Institute in Budapest.

The institute at Martonvasar is situated in the countryside with ample space for laboratories and greenhouses. It is in fact the largest plant breeding institute belonging to the HAS. It has projects in both the basic and applied areas of science. These include for example the preservation and expansion of genetic variability, the production of raw materials for healthy nutrition, the development of durable stress resistance and improvements in seed

safety. The departments of the institute are as follows: the plant cell biology department, the genetics and plant physiology department, the applied genomics department, the maize breeding department, the crop production department, the cereal breeding department, the cereal resistance breeding department, and the phytotron department. The phytotron facility, according to European standards, is a particularly impressive array of over 50 plant growth units, each able to control light, temperature and humidity on independent programmable cycles, therefore having the ability to simulate weather conditions in any part of the world (photo available, see Appendix E). The institutes list of publications in international journals is extensive, but it also has a number of hybrids registered inside and outside the EU. It holds patents for agricultural production techniques. The Institute houses a gene bank that contains over 6000 'accessions' of wheat genotypes and other cereal species (*Agropyron*, *Hordeum*, *Avena*, *Secale*), together with genetically valuable stocks developed in the institute or obtained for research purposes from foreign gene banks. In addition to collecting and storing gene sources and to identifying and classifying cereal species, the gene bank is involved in the preparation of a catalogue containing the major morphological and economic properties of the species. (Belea et al., 1994). There are companies partly owned by the institute which have the aim to distribute products and develop solutions with actors further down the innovation chain.

The head of the applied genomics unit, Professor Ervin Balazs was previously a founding scientific director at the Agricultural Biotechnology Centre (ABC) in Godollo before stepping down in 2000 and moving to Martonvasar in order to continue the work on the development of molecular tools by setting up a DNA chip laboratory. The applied genomics unit currently has genetically modified potatoes and wheat in field conditions

undergoing trials. Previously this department had close ties with the tobacco research station in Debrecen whilst field testing tobacco over a period of 10 years. Particularly good connections have been developed with research institutions in South Africa working in partnership on similar projects. The department has one material transfer agreement with Monsanto. That is the freedom to use a genetic sequence developed by Monsanto for experimentation and data gathering. The researcher was given to understand that there was no payment made for this. This appears to be the limit of collaborative efforts with private industry.

The Plant Protection Institute (PPI) in Budapest started life in 1880 as a research station set up to detect and combat disease effecting grapevines. It was adopted as part of the HAS in 1982. It now covers all aspects of plant protection: biology of pathogens, pests and weeds, physiology and biochemistry of plant resistance to diseases and abiotic stress factors, interactions between pathogens or pests and their natural antagonists, the potential of biocontrol, and the development of environmentally safe pesticides. The staff numbers some 130 people, of which 50 are scientists. There is one main building in the city centre and another property on the outskirts of the city with green houses and field space leased to the institute by the HAS. Funding comes from the HAS and also from competitive national applications, various international collaborations and European grants¹⁹.

The PPI has had a closer involvement with higher education than many other HAS institutes. Government policy changes that accompanied transition in the early 90s, in a way forced the PPI to work more closely with universities. As it was explained in

¹⁹ <http://www.nki.hu/>

interviews, there are advantages for both organisations. Universities would like to maintain their graduate schools with a high quality teaching staff and the use of the facilities and equipment at the PPI is also a significant advantage. For the PPI, the opportunity to participate in the work of the graduate schools (PhD programmes) is rated highly, but more importantly, the PPI can secure 2 to 3 students who undertake their project work at the PPI. Results from PhD projects often form the basis of project proposals, work which would be difficult to fund in other ways.

More PhD students are needed at the PPI but universities are reluctant to make these students available. Each student has a certain amount of funding for the purposes of paying laboratory costs and supervision. Laboratory heads at the PPI speculate that it is for this reason that PhD students are difficult to secure from the universities. This has become a particular problem after the policy changes which demolished the rights of the HAS to have their own PhD programs. All programs are now only allowed to be administered by universities. Prior to these changes under the socialist system there existed the 'candidate degree'. This was of a higher standard than the western type PhD and based on a longer period of lab based science. At the age of 40 or 50, people normally attained the candidate degree. The next stage was to achieve the DSc – the doctor of science degree, given by the academy. From those that achieved this doctoral degree, members of the academy were elected. This system no longer exists, having been replaced by the PhD system common in Western Europe.

The role of the academy has been the subject of intense and on-going debate for many years in Hungary. There are two main view points. One is that research capabilities should be

transferred to and built within universities. This would enable teaching and research to occur together and possibly allow for better quality teaching to emerge (as discussed in chapter 3). According to some Hungarian academics this would also create a “researcher attitude” to be instilled within students²⁰. In accordance with this argument, the size of the academy should be gradually diminished. Such a movement would be a massive break from the Soviet model. Many others see a definite role for the academy and argue that the academy should be maintained. This then creates a new question – what type of science should the academy be engaged in, and in what parts of the innovation system? The Soviet system maintained the academy as a home for basic or ‘fundamental’ research and the foundation of the innovation system. Many of the leading scientists within the academy were socialised in that system and see the value and importance of preserving a strong base in basic sciences. Applied research in the academy is recognised by policy makers as not being competitive and at the same time, the gap between basic and applied science has been identified as one of the main reasons for poor innovative performance within the academic sector with very few applied research solutions being transferred to the market. In recent years this has led to discussions about restructuring the academy.

Part of the reason for this imbalance can be traced back to the 1970s and 80s. During this time it was estimated that around 3% of GDP was spent on research and development. Due to trade embargos effecting many Soviet states at the time, new technology from the west could not be imported. It was instead reverse engineered, copied and substituted by the country’s own inventions. Demand for these copied substitute products within the Soviet bloc was high due to the internal market generated by the centralised government and

²⁰ Informal conversation with policy researchers

cooperation between the Soviet states. This follower type research occurred in government applied science institutes belonging to the ministry of industry. When the political changes occurred in the late 80's and early 90's, the inner market collapsed. Ex Soviet states were free to import what was often superior and more widely available technology leaving the applied research institutes very suddenly without a cause. In addition to the retraction of funding occurring in all sectors, these drastic changes were the demise of the applied research institutes which all but disappeared²¹.

As can be expected the issue of the role of the academy is highly politicised. The following evidence is drawn from the data collected and is reflective of those experts, scientists and policy makers interviewed. Opinions are reflective of the time and context in which the data is collected. Triangulation between interviews to find internal validity substantiates the evidence outlined here. The present government whilst not openly taking the radical view of downsizing the academy, has given universities the exclusive right to administer PhDs, has strengthened the funding for applied research, cut the budget for basic research, has introduced legislation to bring the academy and the universities closer together and has fostered discussion on the academy's reorganisation. (The fact that these legislative changes have not delivered the desired effect of a well functioning innovation system with a smooth path to production for research innovation and the reasons for which will be discussed later). The opposing Fidez party is in favour of strengthening the traditional role of the academy. The academy itself, at its highest levels has strong lobbying power, access to politicians and is influential not only in the formation of general government policy but in discussions concerning its own funding and survival (interview data, 2006). This may

²¹ Interview with Hungarian Policy Official

contribute to an internal force that has an interest in maintaining the academy as it is, preventing or slowing its evolution.

The position and structure of the HAS in the current innovation system is symptomatic of the path-dependencies and institutional lock-in described in chapter 3. The popular position amongst members, in defending the role of the Academy as a home for basic research, possibly extends from the mindset of 'scientific socialism' during communism. The perspective of innovation that views basic research as the cornerstone of the system is one that is widely held amongst the scientists interviewed. This has translated into activities, attitudes and behaviours that maintain a forceful distinction between basic and applied science.

The distinction between basic and applied science is also maintained by the physical structures of the system such as the HAS. By allocating basic science to one entity and applied to others such as those described below, the possibility for smooth transition from one to the other is limited. The structures themselves are prone to the lock-in described by Niosi (2002, see chapter 3) motivated by survival instincts and defensive strategies. The lobbying by senior Academicians to maintain the role and structures of the HAS is one such strategy.

Some limited connections are maintained between the HAS and the institutions that originally undertook innovation and product development. These are described below. The maintenance of these connections are coincidentally part of the system, they do not define the system and are under-used. They are informal institutions that result from pre-existing

friendships between department and organisation heads. Since no influential network organiser as defined by Radošević (1999, see chapter 3) from either the private or public sector, has stepped in to fill the gap left by the retraction of the state, science development centres around the goals and capabilities of particular individuals. The role of the individual is important in the identification of potential pathways and dead ends, as described by both Nelson (2007) and Etzkowitz (1998, see chapter 3) and this is exemplified by individuals identified and interviewed in this chapter and the next.

5.4. Government Research Organisations

Within this category are a large number of organisations. Below described are several of the more significant ones for the purpose of illustrating how such institutions became established and their role in the innovation system.

The Cereal Research Institute Non-Profit company for example is occupied with the breeding and research of cereals, maize and industrial crops. It has been involved with the development of genetic resources since 1924. It currently employs over 300 people, has an annual income of 2 billion Hungarian forints and has a total available growing area of approximately 1 million hectares. It was established by the Ministry of Agriculture and Regional Development with the aim to develop plant varieties that have economically desirable traits such as stable and high yields, disease resistance etc. The institute has five divisions in various parts of the country: the wheat division, the maize division, the division of industrial crops, the field crops research station and finally the division of biotechnology and resistance research. While the selection of traits is mostly achieved through classical

breeding techniques, within this last division mentioned there is an increasing capability to use genetic engineering and tissue culture techniques to assist in the selection and breeding. They have in the past undertaken field trials of transgenic maize. Partners in this 1993 and 1994 project included the Biological Research Centre (HAS), Hoechst A.G. and Frankfurt A.M (Germany). Its successes include the 7 registered wheat varieties in the wheat division, of which 4 are patented in Hungary and 3 in Slovenia. The maize division also has 16 maize hybrids registered in Hungary and 11 registered in Slovenia and Turkey.

The Central Food Research Institute (CFRI) in Budapest was created from a division of a pre-existing organisation, the Canning Meat and Refrigeration Institute, which itself has ancestors. The CFRI came into being in the 1950s as the departments of this large institution became independent. The Institute is funded by the Ministry of Agriculture and Regional Development though EU programmes (for example the framework programs) are also a source of funding. The work undertaken at the CFRI is a mixture of basic and applied research. There are 5 main areas of research; on traceability and detection of biological and chemical risk factors, development of new methods for investigating food safety in line with new requirements, research on biochemical and nutrition-physiological food components, the development of environmentally friendly food processing and risk management and risk communication.

The Bay Zoltan Foundation in Szeged is named after one of Hungary's most prominent scientists. It was established in 1992 by the National Committee for Technological Development (OMFB)²². It is a non-profit organisation that owns various research and

²² Now the Research Development Under Secretariat of the Ministry of Education, OMKFHA

development institutes. Engaged primarily in applied research, its aim is to develop and adapt technologies. The labs of the Bay Zoltan Foundation undertake consultancy type work for private firms, providing results for specific experimental work on request. In recent years, the foundation has developed a new aim; to teach agricultural technologies by the establishment of development centres, supplementing university PhD courses and training researchers.

In terms of large government research institutes, the Agricultural Biotechnology Centre (ABC) in Godollo could be described as another of the new kids on the block. It is amongst the largest of the research institutes sponsored by the Ministry of Agriculture and Rural Development and has 155 employees (75 of which are scientific staff). The research laboratories are modern and well equipped. Though the institute has greenhouses, it does not have field space. It was founded by the Ministry of Agriculture and Regional Development in 1989 based on the policy aim that biotechnology and more specifically, its application would be essential to Hungary's future competitiveness in agriculture. The government in the years prior to the establishment of the ABC, had identified the strong position held by Hungary in the rankings of basic science but had noted that the path from basic to applied science was not functioning well. Its answer was to build this and other such institutes in an attempt to fill gaps in the system.

The ABC has one spin off company: BIOMI Soft Flow Biotechnology, which provides services such as GMO analysis for detection and quantification of modified DNA sequences (providing EU accredited results), DNA sequencing and oligonucleotide synthesis. This spin-off company is reported to have various university and private partners.

The ABC hosts 13 working groups specialising in different areas of ag-biotech. These working groups select their own fields of research. Interviews were carried out with one particular working group in order to achieve some sense of its aims and functioning in relation to the wider institution and partners outside the ABC. The potato molecular breeding group is headed by a scientist whose previous work was at the University of Szeged, then the Biological Research Centre in Szeged until 1989 before being commissioned to take up a place as laboratory head for a working group at the ABC. The work of the potato group is focused on the isolation of useful genes for example disease resistance or stress resistance found in wild species. Since the breeding of transgenic varieties have been banned in Hungary, the gene is not transferred, but instead molecular markers are developed which assist in the selection of the trait with classical breeding techniques. The group is also involved with metabolic analysis – the detection, identification and quantification of different compounds for example glucose, fructose, in various potato species. The potato group is currently involved in several collaborations, with Gail in Germany, Wageningen in the Netherlands and the CGIAR²³ CIP centre in Lima. In order to conduct field trials, it enlists the assistance of the Potato Breeding Institute in Keszthely. The group has 7 staff, the majority of whom are PhD students, registered at the neighbouring Szent Istvan University, but who undertake their project work at the ABC. Co-operation with universities extends a little further than the presence of PhD students in the lab, the head of the unit on occasion teaches specific courses and delivers lectures at the graduate school of Szent Istvan. Interviews at this department did not uncover any collaboration or contracts with the private sector.

²³ Consultative Group on International Agricultural Research

Table 3 provides a summary of the agricultural biotechnology government research organisations in Hungary.

Table 3: Summary of Agri-Biotech Government Research Organisations

Organisation	Year of est.	Size	Main Activities
Cereal Research Institute	1924	Employees: >300	Development of species with modified traits (high yields, pest resistance, etc.). Applied to field and industrial crops. Techniques use classical breeding and genetic modification
Central Food Research Institute (CFRI)	1950's	Employees: approx. 90	Traceability & detection of biological and chemical risk factors, development of new methods for investigating food safety, research on biochemical and nutrition-physiological food components, the development of environmentally friendly food processing, risk management and risk communication.
Bay Zoltan Foundation	1992		Experimental consultancy work Teaching
Agricultural Biotechnology Centre (ABC)	1989	Employees: 155	Classical breeding and genetic modification of crop plants. Teaching. Development of molecular markers.

Here again amongst this group of research organisations, there is a specific lack of connection or integration with the private sector. The structure of the science system during socialism suited the purpose for which it was intended, namely the follower type research that generated products and innovations for the CMEA internal market. This physical and institutional structure in public sector research, is ill suited to product development and innovation that requires feedback from the market and secondary developers of the technology.

Chapter 3 introduced the theoretical proposition by Green et al (1999), that there may be a mismatch between physical technologies and the institutional arrangements which are necessary to accompany their take-off. This is the case here where innovative capabilities which lie in the public research sector are unattached to institutions that link them to possible commercial applications and commercial expertise.

5.5. Universities and Agricultural Colleges

“In the Soviet era, if you wanted to get a good job, a leading position, you had to be a communist, a party member, not a good expert. And because this system was working for 50 years, society suffered big disadvantageous changes. However, there is a conserved portion of society that you cannot ruin from one day to another ...Education was a system like this, they could not spoil it rapidly. Before the war we had an excellent education system in this country: a Prussian type education. We had a strong German influence before the war ...So we inherited a good school system in 1945 and this system somehow survived the Soviet rule. This system raised a good intellectual class who stayed in the country simply because they were not allowed to leave.... The intellectuals had to work for communism but at the same time they helped to maintain the country’s cultural and technical level. And then came 1990.”

(Interview with Professor L.Hornok 2006)

This is the beginning of the story for universities. Funding matched the object and purpose of the education system. But now after transition, the economy faces different needs and has created a different and much reduced funding system, but it is working to maintain the

same structures. There are an estimated 73 universities and higher education colleges in Hungary (interview data, 2006). Under the Soviet system there were 'single subject' specialist universities. Being little more than teaching factories, they were less expensive to maintain than the more modern western perception of research and teaching combined institutions. Generally the agreement is that 73 universities are far too many for a population of 10 million people, 2 million of whom live in Budapest. Smaller towns wish to have the status and funding of larger towns and their determination to prevent closure makes reduction of this number difficult. People in poor regions of Hungary cannot afford to send their children to the well developed areas of Budapest, Szeged and so on. The government is reluctant to engage in a policy of university closure, an undoubtedly unpopular scheme amongst the general public.

This has several consequences. Funding is more widely dispersed instead of being concentrated. The same could be said of teaching staff and student numbers leading to smaller class sizes and an over-stretch of highly qualified teaching staff. In order to reduce costs universities in the recent past have begun to close programmes such as biotechnology which are immensely expensive due to the lab space and equipment required. These are dropped in favour of the cheaper classroom or 'text-book' based subjects. (Interview with L.Hornok, 2006)

Widespread university closure not being an option, the government's alternative was to merge the single discipline universities. In some cases this was successful and in some cases, less so depending on several factors. For example in Debrecen, university leaders were keen to integrate the previously existing higher education institutes in the town and to

facilitate the integration they were able to secure a few grants from different sources. In other cases where universities merged due to government pressure with neither the financial resources nor the common interests and motivation, integration was unsuccessful (Interview with Professor at CEU, 2006). Field work did not uncover why such additional financial sources were so determinative in the success of integration, but it may be supposed that common infrastructures would have been needed, or perhaps increased reorganisation and bureaucratic machinery, networking arenas, or new combined research lines or courses.

Agricultural science (and the same could be said for sciences generally) is still taught as a single disciplinary subject. Very few universities offer the opportunity to take secondary options in business, management, IT, etc. This may be one contributory cause of a lack of entrepreneurial culture amongst science graduates of past generations. Corvinus University in Budapest is one exception. Professor Janos Balint runs a five year horticulture degree course. Students are taught horticulture and biotechnology, alongside the basics of agrarian management, law, book keeping, marketing and economics. Professor Balint undertakes some limited secondary source-based research and has been able to publish work. Funding for teaching comes from the state and from student fees and there is a little additional state funding for the research undertaken at the department. There are several PhD students registered with the department who work mainly on campus but they are able to use the superior lab facilities at nearby research institutes.

The additional subjects in management, law and so on taken by horticulture students at Corvinus are not the same as those offered to other students of the university. They are not modules belonging to other courses, additionally taken by horticulture students. The

departments within the university remain boundaried. Though government policy was to merge universities, true cross-disciplinarity within universities takes much longer to achieve. As it was explained:

“In several cases if the professors are not ready to collaborate because of understandable and non-understandable reasons, you cannot develop a joint programme. At this university we have a language department in this building and a language department in another building and they don’t have a common teaching curriculum. A couple of years ago it was extremely difficult to offer courses for different faculties at the same time because every faculty tried to keep their own students. It was very irrational... The teaching curricular was heavily influenced to preserve jobs and not for any other reason.”

(Interview with Professor, CEU, Budapest, 2006)

Salaries for scientists in both the public and teaching sector remain low. Science, and in particular, plant and agricultural biotechnology is reported to be ‘not in fashion’ leading to lower intakes at all levels. Even as undergraduates, students are aware of the salary and career prospects and make decisions early about whether or not to enter certain fields²⁴. After gaining PhDs, the majority of students find positions abroad, very often in Germany, the UK and the US. Informal conversations with students suggest that most would rather stay in Hungary but opportunities at home are scarce. Expectations are that the academy will go through a second wave of cuts 2007/2008 as a prelude to a second planned reform (Interview with Hungarian Scientist, 2006).

²⁴ Informal conversations with ag-biotech PhD students at the ABC, Godollo

Successful universities match the geographical positioning of the larger better known research institutes: Budapest, Godollo, Szeged and Pecs. There are thus identifiable 'centres' of biotech in Hungary where theoretically the dynamics of regional innovation systems could be fostered. However, there is not enough other private and spin-off activity occurring to call many of these biotechnology 'clusters'. The absence of any strong connections between universities and research institutes are not conducive to such dynamics. The universities shortage of funding means that the government support that accompanies PhD students is extremely valuable, and so universities are reportedly reluctant to allow them to undertake work outside of the university:

"There are conflicts of interest between Szent Istvan University and the ABC. The ABC doesn't want to put money in here for nothing, but they would like to get more PhD students who are highly motivated cheap workers. On the other hand, the University wants to keep its PhD students for its own purpose... The Universities get money from the government for the students stipend and for their teaching expenses as well. The universities have to transfer this money to the research institute if students are allocated there. On the other hand the university professors want to have this money together with the PhD students whom they can use for teaching". (Interview with L.Hornok, 2006)

And a similar view point from an academician; "The universities are fighting against us."
(Interview with HAS Scientist, Budapest 2006)

Gradually ties between the research institutes and the universities have begun to develop. For example Ervis Balazs from Martonvasar teaches a six month course on the legal and

ethical issues of GM crop science. The head of the Potato Molecular Breeding group at the ABC in Godollo on occasion gives special courses at the neighboring Szent Istvan University. The PPI in Budapest has various staff members who are associated with university departments. This cooperation though forced by changes in the law in the early 90s has benefits for both sides. As mentioned above high ranking staff members from the PPI can be nominated as supervisors for PhD students, students can make use of the superior lab facilities at the PPI and the universities need well qualified research staff to teach on the grad-school programmes. From some corners such connections are regarded with skepticism:

“You might have difficulties to understand why I have two jobs; one at this university and one at the nearby Agricultural Biotechnology Centre. This is indeed a ridiculous situation. I came to this university 13 years ago at the invitation of the rector, who wanted to employ some people who are well known experts at least within the country, just to show he can improve the quality of the university. And he invited some four or five people like me. But we didn’t want to join at 100% capacity because of the low level of this institute. Another reason is that the university has no money to finance a department like this... It is me who can finance such a department from my research grants, but it is a kind of mis-appropriation of the money. When I leave this university, there will be no-one to finance this department and it will disappear... The Szent Istvan University has an advantage because of the physical proximity of the ABC. Both my MSc and PhD students can do their laboratory work at the ABC as long as I keep my laboratory there. But this is based on my personal links and if these links are interrupted because the director of the ABC doesn’t want to

maintain it or I lose my energies, this kind of education will collapse at the Szent Istvan University.” (Interview with L.Hornok, 2006).

Various opinions of the standards of PhD students exist. On the whole, supervising staff at the research institutions are satisfied with the competency of students, though usually they are able to select amongst the brightest and most promising for the few coveted places available at the institutes. However, there are some indications of a lower over-all comparative standard of universities and the PhD programs. Laszo Hornok as vice rector and leader of the PhD school at Szent Istvan attempted to make the PhD qualification dependent on a prerequisite of 2 international papers written by the PhD student and their supervisors. This was met with great opposition, apparently due to the inability of most departments to meet this standard. He alleges also that heads of departments are not committed or competent enough to finance university research by the writing of proposals and winning of grant money. (Interview with L.Hornok, 2006)

One legacy of communism that particularly effects universities even now, is the conversion of universities to ‘teaching factories’ and the removal and transfer of research capabilities to the HAS and other government research organisations. It is a complete reversal of the Humbotian model developed in Germany and the US (see chapter 3). The informal behavioural norms that accompanied the ethos of ‘open science’ which is a factor that greatly contributes to innovative potential and the innovation system framework, remains underdeveloped in Hungary.

The role of universities as ‘knowledge generators’ and ‘knowledge exchange agents’ (Koschatzky, 2002) is further undermined at present by the general reluctance amongst universities to foster integration with others in the research sector for example by releasing PhD students to the tutorship of other organisations. The data shows that there are some ‘soft transfer’ activities occurring with visiting teaching staff but cooperation is not as yet being developed into more formal contract activities.

The isolation of the universities and its lack of ties with other actors, from an NIS perspective limits knowledge flow and knowledge accumulation. The transfer of people out of universities may keep a supply of qualified personnel in the system, but the universities fail to achieve a more integrated role in the development and production of any real innovations. From the triple helix perspective, since innovation and technology drives and is driven by the transformation of the helices i.e. the institutional relationships between industry, academia and government, the limitation in the development of one actor (in this case academia), will limit the others and the evolution of the system. This theoretical proposition is reflected in the very real observation that because universities are not integrated into the innovation system, there is no entrepreneurial or innovative culture therefore limiting the formation of boundary actors such as spin-offs (described later in the chapter). This demonstrates how the extent and activities of certain actors in the innovation system are constrained by the limitations of another.

5.6. Private enterprise and enterprise assistance

Large multinational companies have had in the recent past, an influential role in Hungarian agriculture. Companies such as Monsanto, Syngenta, Bayer and Pioneer have representative offices in the country. These multinationals are well established as conventional seed and pesticide producers. Most could not be contacted and the two that were, refused permission to be quoted or recorded. This is hardly surprising considering the massive negative impact of the media's framing of the GM crop issue.

According to scientists in the public sector when asked about potential for cooperative research;

“We would like to have this, but they don't want to. ...They don't want Hungarian research”

“We are carrying out principally basic research and its not easy to find academicians with common interests with the companies. We don't have much personal contact. We have many contacts with universities but not with industry”.

Interviews with Hungarian scientists, 2006)

However, an interview with a leading person at a large multinational, reveals that the situation is more complex than simply a case of disinterest. Conversation alluded to two events. Firstly work by the Plant Protection Institute on one of the commercialisation candidate GM crop species showed results of increased risk of disturbing other species. These results were forwarded to the EU commission as supporting evidence for upholding

the moratorium. The ban on field trials for certain species does continue, and for commercialisation of any GM crop, but it unclear as to whether the EU will continue to support this²⁵ or whether the results produced by the PPI were influential. The results are contested by the multinational. Secondly, during the initial considerations of a Hungarian biotech policy in line with the new EU requirements, a GMO roundtable of 17 people was established. The majority of these were representative of organic growers and green associations. Two members however were prominent pro-GM scientists who left at the first meeting due to the reported hostility of the environment (Interview 2006).

Another academic commenting anonymously on the linkage between public and private organisations:

“The Hungarian government promised at the end of every government term, that they will raise research funds for the next term. After the elections they never did. Instead they decreased it. And we have a rule now that all researchers and academic staff have to provide, have to contribute to her or his salary from research projects funded by private companies, so that’s why we are forced, even if we are doing basic research, to deal with companies. And sometimes these companies ask “little things” in return. So I have to say that they are forced to do that, they are forced to negotiate with these big companies and I can imagine that some of these academics have bad nights sometimes but they have to do this because they have to care about the mere existence of the institution, they have to provide a salary for their employees and so on.”

²⁵ Hungary’s restrictive stance on commercialisation (the draft bill for co-existence) is currently being negotiated and debated with the Commission. The interpretation of the precautionary principle appears to be the main sticking point. Hungary’s policy was subject to investigation on at least one instance due to the 400m isolation distance, regarded by the Commission to be excessive.

In addition to large MNCs, there are much smaller national companies. Since staff from such companies are educated in Hungary and have undertaken postgraduate research at either one of the universities and sometimes also at a public research institution, the connections between these smaller companies and the NIS, is much closer and more involved. Green Controll BT for example is a small microbial bioremediation company based in Szeged and Budapest. It was established by four founders who met and completed their PhDs at Szeged University. Start up funding came from a government initiative in 2005 – an open proposal for new technologies. 100,000 euros were won by Green Controll along with another 130 companies in a competitive process. The founders of this small company design experiments and contract the laboratories of the Bay Zoltan Foundation in Szeged to carry these out. Working on the results as a desk based exercise, the company can then develop this type of bioremediation technology. It is a relatively short term project, in the near future the company hopes to sell the technology and undertake a new project though outside of Hungary, perhaps in Romania or the Ukraine where they judge the market for these techniques to be more promising (Interview with Green Controll BT founder, Istvan Vesselenyi, 2007).

There is a major problem in the Hungarian biotech business environment. There appears to be a lack of institutional support for the additional skills required for new start up companies and university spin-offs. Scientists do not have business expertise, management skills, marketing knowledge etc. when they consider for the first time the possibility of a business enterprise. Universities occasionally have technology transfer units that might deal with patents or spin-offs, but these are rare, understaffed and under-funded. Not only this, but it is reported that rather than establishing a spin-off universities would rather

patent and sell a new technology, an activity which is judged as far less risky. This leaves the scientific community with no experience, knowledge or inclination to start up a company. However, gradually attitudes are changing in cities such as Budapest and to an extent, Szeged (Interview with K.Kovacs, Szeged, 2007).

Once again the state has stepped in with an experimental solution to fill the gap. Biopolisz is a technology transfer firm, unique in Hungarian agricultural research, established in 2004. It was modeled on Western European examples. Ownership is divided amongst four partners – the Biological Research Centre, Szeged University, Szeged local authority and a regional investment firm. The objectives of the academic partners are to manage new intellectual property and to commercialise newly developed technologies. The objectives of local government are to assist in the management of early stage development for small business entities and the objectives of the regional investment firm is to find and exploit new technologies. These diversified objectives are united by a small team of dedicated staff numbering 10 people who have expertise in spin-off management, general office management, marketing, commercialisation, intellectual property law and patenting. Many of the staff have moved into the business management sector from previously existing careers as scientists. By creating a ‘one-stop-shop’ and providing close and detailed support, it is the mission of Biopolisz to protect ‘academic freedom’ by allowing scientists to progress in their work without having to dedicate time to learning business management skills. Biopolisz has had experience now with a number of fields including laser optics, nanotech, agri-biotech and environmental sciences.

It has been so far, a profitable business organisation. Though as can be expected much of the start up capital that was granted to it in the initial stages was absorbed. Funding from the cooperation of the four owners gave this firm a unique opportunity and in the same way that such cooperation is unlikely to arise again, this is likely to remain a unique organisation in the NIS.

5.7. Boundary Organisations and the Links Between Institutions

There are key interactions between the institution types. Referring back to figure 5, these links are labeled a – e. The following examples illustrate the strength of these and sometimes the nature of the organisations that evolve from linkages.

a) The link between Universities and the private sector

It is reported that Szeged University generates as many as six spin-off companies a year (Interview with I.Molnar, Szeged, 2007). This study was not able to identify any that specifically dealt with plant biotechnology but it is entirely possible that they do exist.

More commonly within universities are the unofficial consultancies that often make use of university facilities and supplement the income of lecturing and research staff²⁶.

b) The link between universities and the HAS

²⁶ From an interview with L.Hornok, 2006 and corroborated by informal conversation with a Pecs university administrator.

Area b describes two types of possible links. Firstly those that have been described above i.e. scientific staff from the HAS teaching various specialist courses for post-grads at universities and the sharing of PhD students. Government policy has been to encourage the sharing of teaching staff and the establishment of HAS groups within university departments, though these ties are not particularly strong.

It is possible to have a second type of institutional arrangement which shows a more integrated approach. Unfortunately this study could not find such arrangements in the plant sciences. But an example exists in the field of micro-biology applied to bioremediation. The Biological Resource Centre in Szeged uses modified bacteria in bioremediation (decontamination and elimination of environmentally hazardous materials). The research is divided into two laboratory spaces, one within the Biological Research Centre belonging to the HAS and a second laboratory space within a short walking distance at the department of biotechnology at the university of Szeged. Both laboratories are headed by Professor Kornel Kovacs who leads a coordinated research programme. The group has been successful both in securing EU grant money and a number of contracts to find bioremediation solutions for industrial clients. The reason for which this may be judged as a more integrated approach with regards to the NIS, is because it brings together institutions such as the HAS, normally engaged with basic science, in order to unite with applied biology and solve a specific problem. The institutions unite in terms of organisation to solve the problem but also have begun to build together a set of associated expertise and a body of knowledge.

c) The link between the HAS and other government research institutions.

Connections have gradually been established over time. Both institutes visited, the Agricultural Institute at Martonvasar and the PPI in Budapest, regularly use the facilities and expertise of the classical breeding centers. The centers of course have their own role in agriculture in the detection of new pest problems and the provision of conventional plant breeding research but they act more within a service role for those involved in biotechnology.

d) The link between the private sector and other government research institutions.

There are few examples of this type of connection. The Bay Zoltan Foundation with its modern facilities and scientific capability has the potential to provide a service that would be useful to the private sector. Green Controll BT is a new type of emergent business organisation in Hungary. As mentioned above, its activities involve the production of industrial bioremediation solutions though its founders are able to do this solely as a desk based exercise, outsourcing all of its laboratory work to Bay Zoltan.

e) The link between other government research centres and universities.

The present research found only one example. The ABC in Godollo has several arrangements with its neighbour, Szent Istvan University. PhD students undertake work at the ABC while registered at the university and staff at the ABC teach specific courses at the university. More unusually Laszlo Hornok heads laboratories at both facilities, though the

goals and problem focus of the two labs differ, they are not strongly united around a single research problem such as in the case of the Szeged Biological Resource Centre.

5.8. Role of the State and S&T Policy

2002 – 4 figures show that enterprises with innovation activity as a percentage of all enterprises is 21%. This is far below the average for the 27 EU countries surveyed by Eurostat which gives a figure of 42%²⁷. R&D expenditure as a percentage of GDP is also low at 1% in 2006 compared to the EU27 average of 1.84%²⁸. Inzelt (2004) suggests that the state budget still funds the main part of all R&D activities in the country.

After declining in the first years of transition, the budget recovered slightly in the latter phase. Public funding is divided amongst the HAS R&D laboratories (approximately 55%) and the universities (approximately 40% in 2000). The role played by businesses was around 5% at that time. 2001 - 2004 saw an increase in funding from foreign sources which mostly reflected growing involvement of national actors in EU and other internationally funded projects (Inzelt, 2004).

As discussed in Chapter 2, a comprehensive law on GMOs has been in place in Hungary since 1999, complying with EU Directive 90/220. Hungary currently has a de facto moratorium in place for the commercialisation of any GM crop and a ban on the field

²⁷
http://epp.eurostat.ec.europa.eu/pls/portal/docs/PAGE/PGP_PRD_CAT_PREREL/PGE_CAT_PREREL_YEAR_2007/PGE_CAT_PREREL_YEAR_2007_MONTH_02/9-22022007-EN-BP.PDF

²⁸
http://epp.eurostat.ec.europa.eu/pls/portal/docs/PAGE/PGP_PRD_CAT_PREREL/PGE_CAT_PREREL_YEAR_2008/PGE_CAT_PREREL_YEAR_2008_MONTH_03/9-10032008-EN-BP.PDF

testing of Mon810 wheat variety proposed by Monsanto. Chapter 2 has already detailed these facts, but it is appropriate here to gauge the character of the state as one of the main actors which defines the context. This will become important in the next two chapters as the project considers innovative potential under conditions of political uncertainty and innovative potential in networks. In addition to the data collected by interview, it is possible also to draw upon the work undertaken by academics who have studied Hungarian policy making institutions.

The role of the state has been discussed extensively. Here I draw upon one or two sources which specifically look at the role of the state in the science and technology systems in transition economies.

Pavitt (1997) is one author who writes about the role of the state under these conditions. He suggests that the policy making process, typically of Central and Eastern Europe (CEE), suffers from a lack of policy coherence and high levels of political, legal and economic uncertainty which discourages investment. Second, the shift from state control to privatisation may be excessive, leading to a situation of going from complete planning to almost no-planning. The functions of the state with regards to the science and technology system in CEE should be:

- Privatisation of public knowledge: based on the assumption that basic research would be more economically useful if it were constrained to seek and fulfill R&D contracts for private firms. However, Pavitt comments that policy can be distorted if governments show “excessive zeal for the privatization of public knowledge” (Pavitt 1997, p.55)
- Support for technological change in specific sectors.

- The establishment and maintenance of standards.
- Regulation to deal with negative externalities (e.g. safety, pollution).
- National systems of finance, management, education and training.

According to Inzelt (2004), the Hungarian government is gradually incorporating many of these functions into its role. The government of Hungary has had to redefine its role from ruler and regulator to a facilitator of the R&D system.

One of the programmes initiated by the government in its role as a facilitator is the sunrise R&D programme which aims to promote industry-university cooperation by supporting applied research and experimental development through competitive calls. The Sunrise programme, funded by the Hungarian Central Technological Development Fund (KMUFA) redistributed 12% of the governments R&D expenditure in 2000.

Since 1995 the KMUFA has also supported programmes such as “Promotion for applied research” and “Biotechnology 2000” which aimed to give priority for projects which involved collaboration between university and industry (Inzelt, 2004). Interviews with staff at the NKTH in 2006 pointed to the recent addition of the “Innocheck” programme which offers funding for businesses that would provide the service infrastructure necessary for an innovation system i.e. law, accountancy, marketing services.

Inzelt has suggested that many of these programmes have limited impact for several reasons including the transition crisis and the resulting limited funding available, the “gap

toothed nature of regulations”²⁹, and the funding scheme itself which shows a policy thinking closer to the linear model of innovation rather than a model based on feedback.

Janike et al argue that the successful implementation of policy does not occur through the sole use of a single policy instrument but rather depends on attaining institutional capacity and the flexibility to use a combination of multiple tools over time (Andrews, 1997). Institutional factors which limit capacity include “political and legal structures and the rules and norms that produce a framework for interaction. In this area, participation, integration, decentralisation and the capacity for strategic planning are seen as particularly important” (Murphy, 2001).

As will be demonstrated in the next two chapters, it is not a vacuum-like policy gap that was theorised to exist, which creates a problematic framework in which innovative actors have to cooperate, it is a weak capacity for policy integration in particular sectors. Innovation policy and law do exist, but funding for effective implementation is low and interviews show that communication across government departments is non-cohesive in terms of policy making for an interdisciplinary sector such as biotechnology. The government follows a linear way of thinking and seeks to ‘plug the gaps’ in the innovation system by building new organisations (such as the ABC).

²⁹ For example, the ownership of inventions had not yet been clearly regulated at universities at the time this article was written in 2004. However, the Innovation Law which had been passed at the time of fieldwork in 2007, it is understood from interviews with academics, that this had gone a long way towards correcting some of these gaps.

5.9. Conclusions to Chapter 5

This chapter demonstrated four main categories of actor which are involved in crop agricultural biotechnology in Hungary. These actors carry out both applied and basic research in GM crops and are venturing into some new areas of specialisation such as molecular marker development, traceability, detection, teaching and so on. Boundary organisations which develop from interactions, or create links between two categories of actors are few in number but have increased in recent years making for a more comprehensive innovation system. Links at the moment are mainly only bilateral and very rarely connect more than two categories of actor. The most obvious feature remains the lack of private and industrial organisations (both national and international) which would have the ability help integrate innovation activities with market demand.

The inherited education system has various associated problems. First there is the large number of universities and colleges with a lack of resource concentration in key areas such as science. This leads to the closure of many university biotechnology departments in an unplanned, un-strategic manner. And second, the lack of teaching staff due to universities being mere teaching factories with the best researchers being absorbed into the HAS during the Soviet era. As a result of these problems, universities have difficulties in developing the research culture that would be called upon by the Humboltian model if such a policy were to be advised by government, which looks increasingly likely as Hungary moves into line with the EU agenda as specified by the previously described EC communication of 2003 (see chapter 3). Teaching remains still quite apart from research though inroads are beginning to be made with HAS and government lab research staff starting to teach courses

at universities and PhD students beginning to make use of placements in HAS and other public research laboratories. Occasionally these efforts are frustrated by the reluctance of universities to relinquish the bench fees that accompany research students.

The structure of the innovation system reinforces the distinction between basic and applied science. The linear innovation model that dominated the pre-transition era created this distinction through both the physical structures of the regime and the thinking that pervades, prevents a more integrated system of science, industry and innovation. Through the lens of NIS theory it is possible to see that the institutions which existed in the pre-transition era are being maintained through the self-interest of the primary actors involved. There is a path dependency that exists due to the cumulative effect of many years of funding dependency on the state who was the only network organiser for many years (see Radosevic, 1999 in chapter 3). With no alternative organiser emerging from the private sector or otherwise, such institutions remain intact.

It may indeed be possible to investigate the separation of the basic and applied system of science through bibliometric or other quantitative indicators. However there is difference between the description of the organisation, the department, the approach to science and the outcomes. For example, an organization may be generally described as one which has been established as home or for the purpose of basic science, it may though, be producing outcomes which are better described as applied science. If a genetically modified plant is produced but is used to study the basic mechanisms of drought tolerance, the question of whether this is basic or applied science may again be questioned. In practice the boundary between basic and applied science is not clear. It must also be considered that the outputs

and contributions of an organisation, department or individual also are not always tangible or quantifiable, let alone assessable in terms of their being basic or applied. A qualitative ethnographic approach is better suited to this investigation.

Irreversibility or lock-in (examined in chapter 3) is demonstrated by the maintenance of these institutions, the physical research structures and their role in the system. It stems from cumulative learning and behavioural patterns that have evolved over many years. In other words, a culture generated in the first instance by the 'scientific socialism' of the Soviet era.

The type of lock-in demonstrated is of an organizational or structural kind. It is not a case of allowing for a level of switching costs in order to change a product line. Altering the balance of basic and applied science would require changes at the institutional level and at the organisational level. Not all cumulative learning leads to lock-in. It is dependent on which skill sets and knowledges are gained and lost. In this case learning has for example led to the system depending on state funding. The structure of the science and technology system has then come to reflect the centralised funding with few bridging institutions, spin-off firms or other entrepreneurial organisations. Scientists then recruited into the system continue this pattern of behavior without learning entrepreneurial skills or how to adapt in order to gain funding from other sources. The later chapters show how change is occurring, but this may be an example of how in the past cumulative learning and learned behaviors and practices help to maintain the science structure in its present form.

Further insights are gained by reflecting on the triple helix theory. When looking at the division of labour and quality of the institutions that hold primary actors together, what this thesis has found is a strong core group of actors in the centre of the science system. These actors are undertaking the higher proportion of activity, even if it is centered around basic rather than applied science. However, since this core group of academic scientists maintain their role and are not evolving, other parts of the helix and the system as a whole also does not evolve.

Examples from the data I collected (interviews 2007) show that it is the small firms that have the ability to carry forward in a fluid manner the innovations to the market, but the economy does not allow for small companies' to be set up. Universities do little to encourage the establishment of spin off companies, instead opting for the less risky more profitable patenting and selling option for new technologies. There are a lack of technology transfer offices, law firms, accountancy services etc which are necessary for a private sector to develop successfully. In terms of regulatory and science and technology policy, there is a lack of stable and cohesive policies that should act as a framework for this interdisciplinary area.

It is essentially an old structure with holes that prevents the smooth transition from basic research to product development. This system as it is does not have the institutions to respond to capitalist market signals. Transition occurred only in the early 90's which means that this is still very early in the evolution of the system. It is in many ways still adjusting to the shock incurred by transition and still learning to cope with vastly reduced funding and the connections lost with industry as it receded.

Transition has left some noticeable holes in the NIS such as the lack of any organisations that carry out applied research. Government policy has tackled this problem in multiple ways, by providing financial incentives for new startup companies, by offering larger applied research grants and reduced basic research grants, by policy which encourages universities to have an industrial partner, further policy which forces research institutes and universities to work together and finally by setting up research institutions such as the ABC in Godollo, specifically to fill this hole in applied research. Some of these solutions, particularly the last reminds us that Hungary is evolving from a communist regime and the steps the government has taken are reminiscent of the communist way of thinking. Perhaps there can be no other way. Basic research institutes have not developed the capacity to do applied research, they have not the mechanisms to receive market signals and respond to market demand. And industry and private firms find it difficult to survive in a difficult economic climate especially without the business management skills and support that are necessary in any part of the world.

However, transition was gradual in comparison to other regions and began much earlier. Also because it was amongst the first in the eastern bloc to become an EU member, and because of the cheap but skilled labour, it was assumed Hungary would be used as a springboard by western countries to get to east European potential markets. Thus theoretically capabilities of the private sector for R&D and innovation would have been strengthened more than most and connections with foreign private companies should have been developed. But in agri-biotech this has not happened due to government regulation preventing commercialisation. Market signals cannot be fed into the system anywhere to allow the learning of response and adaptation and development of a technology for

domestic market use. Research that is achieved can only be applied internationally in which case Hungarian institutions will always be seen as a 'service' sector in applied research markets abroad.

In answer to sub question 2 on whether linkages between actors in the network demonstrate sustained use of institutional arrangements that characterised the pre-transition NIS, my data and analysis presented in this chapter has contributed the following: the distinction between basic and applied science that previously existed is reinforced by the publicly funded research infrastructure and the lock-in that stems from cumulative learning and behavioural patterns. The system is further importuned by the lack of research culture in the inherited education system which is frustrated by the immobility of actors. There is however, a strong group of core actors in the centre of the science system which undertake most of the activity in the sector.

Chapter 6: Coping Strategies and System Adaptation

6.1. Introduction

This chapter is the second of three data chapters. Its main purpose is to add to the definition of innovative potential by discussing the use and importance of coping strategies for the innovation system in agri-biotech in Hungary. The previous chapter outlined the main structure of the innovation system as it relates to agri-biotech, describing the actors, their activities and regulatory framework within which they operate. This chapter will feature how their activities have changed in recent times in response to complications in the general and regulatory environment. Complications in the regulation of GM crops arise from the strongly restrictive national legislation adopted by Hungary under the EU overarching framework. The basis for adoption of this national legislation is highly contested.

The chapter will initially look at the various complications that effect the innovation system. The data demonstrates three main types; 6.2.1. examines the current situation of perceived lack in public demand for GM crops and the expectations of the scientists who are the primary innovators in the system. 6.2.2. details the politics surrounding national science and technology policy and the fall in funding suffered by most of the publicly funded research institutes. 6.2.3. lastly discusses the politics behind national GM regulation and how uncertainty results from contestation, partly between Hungary and the EC, but primarily between interested parties within the country.

The chapter then moves on in 6.3 to look at the future as a source of uncertainty in the current context and the problems this poses for long term planning and learning. Following this, section 6.4 pulls from the data the strategies employed by various actors to cope with the difficulties outlined in section 6.2 and an uncertain future as described in section 6.3. The section finishes with a summary table showing the probable long term effects on the innovation system.

This chapter contributes to the existing literature by adding these original findings on adaptation and coping strategies of the core group of actors. It in part forms a basis for answering research sub-question 3 on how context specific institutional factors effect innovative potential in this sector, but also shows the dynamics of the transition process through coping and survival.

The next chapter will take forward one particularly prominent coping strategy, to examine in some detail. This is the networks and collaborations that form between national and international actors which act in many ways to sustain innovative potential in the network.

6.2. Environment Complexity and Uncertainties

Agricultural biotechnology innovation in Hungary occurs in a highly complex environment. There are overlapping environments that frame the space in which the network operates. European regulation creates a particular regulatory environment, as does the national regulatory environment within which it sits. There is also the market environment determined by domestic and international consumers who will use the products of the

innovation system. Consumers in the innovation system are not only households, but also other actors, for example universities who may use patents that are discovered within Hungary or perhaps MNCs. The position of each actor in relation to each environment will also vary. For example, if a research group is hosted within a university department or if they receive funding from European sources and not the national funding system, they may be relatively insulated from the changes in the national environment. Or for example an actor may be more or less tied and exposed to the instability of the market. Multi-national corporations will be directly effected by the actions of national consumers, whereas basic research departments would be less so. Sensitivity to market conditions is partly dependent on how far upstream or downstream actors are in terms of the innovation process.

These conditions are common to many countries, but more unique to Eastern Europe and Hungary are factors such as uncertainty in funding linked to economic instability and contested national politics on the subject of GM and more generally around science and technology policy. Exploring these conditions in more detail, data analysis reveals that sources of uncertainty can be discussed in terms of three main types; 1) the public and demand for GM crops, 2) national science and technology policy and the fall in funding, and 3) regulatory policy uncertainty.

6.2.1. The Public and Demand for GM crops

A strong market signal to those in the innovation system are the reactions of users of real or potential innovations. The most obvious problem in this context is the level of public

hostility towards GM products generally (level 1 concept: 2, 23, point triangulated by various interviews).

A Hungarian PhD student working on a project comparing media coverage and attitudes towards GMOs in Hungary, France and England reports that Hungary has a less negative approach to the GMO debate although there is generally thought to be less of an active or comprehensive debate than in either of these two countries (Personal communication, Sept 06). There is a lack of public involvement in Hungary possibly due to the non existence of forums in which such topics might otherwise be discussed. The farm scale evaluations in UK that took place over three years, (the results of which were published in 2003) for example, involved extensive public consultation exercises which pushed the debate forwards. The resources required to conduct local and national public consultation on this topic are scarce and so this has not been allocated a high priority. Neither have attempts been made to identify, inform or consult with the farming community who form a politically important group. A former employee of the Ministry of Agriculture in the department of biotechnology when asked by the researcher if there are any other people the ministry should have been talking to but were not, answered in the following way:

“Yes of course, the farmers. They missed this step too. This was my other suggestion, to make questionnaires. To go out to the farmers and ask. Because if they don’t want to use it, there is no point in thinking about it, or at least to know their opinion, but nothing, they didn’t contact the farmers.”

A report published in 2005 by Research International Hoffman, a market research company includes a survey of the 100 largest agricultural production companies registered by

Monsanto in Hungary³⁰. The survey shows that only 24% thought they were well informed on the topic but could not give an opinion. 29% said that they were not well, but satisfactorily informed and 46% said they were not well informed. 46% of survey respondents said that the reason that growers would choose a GM crop would be because of expected reduced production costs. 31% said that higher yields would be the motivation for growing GM produce. In general 72% (representing 300,000 hectares) said that they would produce GM crops if they were allowed to. This survey of course does not account for the thousands of much smaller farmers who are more likely to sell to a local market. There is also the opinion that if other members of the EU were to allow GM crops, then Hungary remaining GM free, would provide some sort of niche market and competitive advantage when exporting abroad.

With the absence of certain voices and groups, the debate appears to have been polarized by the increasing and active presence of NGOs. The policy stance held by Hungary, to ban the commercial cultivation of all GMOs and to prevent the field testing of certain varieties, is said by some to reflect the strong influence of NGOs. The former agricultural ministry employee suggests that the ministerial committee on biotechnology has a 60-70% membership from NGOs and the media with the minority from universities or the business sector (point corroborated by several interviews) . True demand and market signals may therefore be disguised and a predicted level of acceptance should GM crop cultivation be allowed, is not known.

³⁰ Document in Hungarian, translated by AKI policy researcher

Activity by downstream innovators is increasingly inhibited by national law, the more applied the science is and so we might expect a certain future of no activity. However, scientists in the applied field continue with the opinion that given the general opposing trends of other member states and other countries globally the competitive pressure being applied to Hungarian farmers is increasing and so an opportunity to improve yields or lower costs, will eventually be accepted (level 1 concept:2, 23, 25);

“Unfortunately the awareness of society regarding green biotech is badly effected ... at least in the short run is very difficult to judge what will happen. I’m an optimist, nowadays there is some small light that maybe the political and social attitude about green technology will be different soon”.

(Interview, Ervin Balasz, 2006)

“If the innovation is ready for application, if it is very useful for peasant, for growers, it will breakthrough without any policy and against the NGOs. Canola can be grown in Hungary but the yields are very low compared with the neighboring Austria. And if a genetically modified canola can deliver a doubling of yields, it will break through.” (Interview, Janos Balint, 2006)

Additional signals confuse the picture such as the growing concern at the EU level in being able to compete in a global market in the growing biofuels sector. As reported in European Biotechnology News in June 2007;

"How can we remain competitive by producing biofuels with just conventional crops? One hectare of conventional corn produces around 6,000 litres of bioethanol, but the same hectare growing GMOs would produce around 14,000

litres - and the progress of research and development lead us to think that this gap will even be more important in the next few years."

Thierry de l'Escaille, head of the European Landowners' Organisation

In the early part of 2008, food prices increased across the world due to the combined effects of poor harvests and competition for land between food crops and biofuels. The data collection for this project which ended in 2007 did not capture the influence of this new concern. This problem though, it may be imagined, would likely be called upon by those in favour of GM technology for food crops.

Lack of a domestic market effects less directly the scientific community than the sellers and distributors of agri-biotech innovations. Multinational agri-biotech companies who in other parts of the world, are engaged in the development and dissemination of GM technology, are not leaving Hungary. Apparently they stay because they have significant investments in the pesticide and conventional seed production and distribution market. It is with some certainty we can guess they are observing (at a distance) the debate and developments with much interest. Katz and Kahn (1978, cited by Birnbaum, 1984) note that high technology companies in the US have adaptation strategies that include invention, diversification, increasing the size of the board of directors and joining trade associations. MNCs in this context show the same adaptive actions. In particular Monsanto is a member of the Hungarian Biotechnology Association, a strategic move grouping the company with pharmaceuticals which they hope will ensure an easier path to acceptance.

Smaller biotech companies that would also be involved in the stage that brings an innovation to the market do not have the resources to diversify, reinvent or employ the adaptation strategies that MNCs do. They are therefore much more vulnerable to market change and uncertainty. This seems to be reflected by the very low numbers and high turnover of SMEs operating in the plant biotechnology area (research observation notes).

6.2.2. The Politics of National Science and Technology Policy

It has become unfashionable amongst economists to talk about ‘economic crisis’ in the former Soviet States. The hardship that accompanied the initial stages of transition, the hyperinflation, massive unemployment and so on, certainly indicated a crisis situation in every sense that cannot be compared to the much improved general economic climate in more recent times. However, the term ‘crisis’ has begun to reappear amongst those especially interested in the long term future of the science and technology system in Hungary. Problems with the national budget deficit surfaced in September 2006. The Hungarian Prime Minister Ferenc Gyurcsany, had been secretly recorded by a member of his own party admitting that he lied to the people and the country was on the verge of an economic crisis. The proposed changes to the government never occurred and the same economic crisis is ever looming on the horizon. The current budget deficit crisis is not a blip and interviews show that it was not unexpected, it is the continuation of an underlying problem that stems from the Soviet era that the present government, like its predecessors, has simply failed to solve. This adds great uncertainty to national funding programs (level 1 concepts: 2, 29).

In an effort to reduce the budget deficit, the government has been reducing public spending in recent years. The fall in available funding fuels the debate on university closure. The large number of universities and colleges struggle to finance their extensive range of programs including molecular biology courses, so leading to the gradual closing down of these expensive departments over time. It has long been thought by many academic staff that the government should take action and strategically close some of these institutions (Interview, anonymous, 2006). Although there has been no definite action in this direction, there has been some forced mergers of universities in the recent past. In 2006 the government recalled the funds that were distributed to universities, promising to return these funds in December. Of course amidst other broken promises, it is thought unlikely that this promise will be fulfilled (several interviews, 2006).

The lack of funding in plant science and the limitations that graduates face in the job market after completion of their university courses is reflected in student numbers. More students enrol on courses for human and animal sciences perceiving the pay and prospects to be better. Of those that do graduate with a PhD in plant sciences, a large number, in fact the majority, leave Hungary for destinations such as Germany, the US and the UK where their futures are more certain. This is creating a widening 'generation gap' in the plant science research sector. The previous scientific generation socialised under the communist regime have settled in Hungary and have no intention to leave. This is the generation currently between the ages of 40 and 60 who are now heads of departments, university vice rectors, research centre directors etc. They are a small network and often know each other personally. The network is likely to become smaller as some of this generation approach retirement. As each new PhD graduate intakes completes, very few stay in Hungary to

create the next middle generation of researchers and teachers. There is a widening gap which presents many difficulties for the future including being able to transmit the learning and skills required for new trajectories in molecular biology and innovation in cutting edge research (level 1 concepts used: 1, 2, 8, 28, see chapter 7 for further discussion on this subject).

There have also been discussions on a possible reorganisation of the Hungarian Academy of Sciences. This would be a yet more dramatic attempt to downsize the funding in addition to the year-on-year cut backs that many HAS units suffer. The land occupied by the PPI in Budapest may be sold by the government to raise funds, forcing the department to move to the countryside (research observation notes, 2006).

The general reduction in national funding is shown to directly effect the future survival of research institutes but it also has the potential to indirectly alter trajectories or directions in science and this will be discussed later in the chapter. Looking more closely at how national policy attempts to directly influence the direction of research and innovation in plant science, we can examine how science funding strategies and science and technology policies are actually perceived.

Rafols (2006) quotes the NKTH budget at 83.1 million euros over 2002 – 2005, this is an average of just over 27 million euros per year. In 2008 the total budget for OTKA was 20 million euros³¹. It is difficult to compare these figures or make a judgement about whether basic or applied science is better funded in Hungary. Rafols suggests that in the natural

³¹ http://www.otka.hu/?akt_menu=991&set_lang=991

sciences, the HAS conducts around half of Hungary's R&D. One may argue that applied R&D is also carried out by private firms. However, Bross et al (1998) adds that the relationship between science and industry is weak and that firms do not carry out enough R&D.

According to the NKTH website, the overall budget for science is being reduced in real terms. Basic science is being reduced (grants managed by OTKA and distributed through the Academy), but support for applied science is increasing (the funds distributed by NKTH)³². However, the conditions under which organizations can apply for applied research grants are proving difficult to fulfill (interviews, 2006).

Opinions both outside of this research and within this research remain divided as to whether basic science or applied science should be supported and promoted. However the NKTH is attempting to improve the rate at which innovations reach the market by means of funding strategies aiming to promote the applied sciences. Despite changes in policy, there is still a perceived lack of direction or national strategy in the area of plant science:

"The problem is that as I mentioned, science priorities in this applied area are not well defined at the moment, so I don't see the priorities. Personally I don't see that there is any scientific strategy for science policy in the country"

(Interview Ervin Balasz, 2006)

Researcher: *"what is your opinion of national policy?"*

Dr Janos Balint: *"my opinion – there is no national policy"*.

³² <http://www.nkth.gov.hu/aktualis-hirek-esemenyek/kapcsolodo-cikkek/eastern-europe-struggles-080519>

The funding strategies for applied science are outlined in chapter 2 and there is certainly a push from government agencies to increase applied science, innovations to market and to improve relationships between the science community and industry. However in this grounded piece of research which focuses on a particular community, we find that despite this, there is still a perceived lack of direction (level 1 concepts: 2, 15, 22). This may mean one of two things; that the message is not being communicated effectively to this core group of people or that this community requires yet more specific direction which is not provided by the government. For example; what kinds of applied plant biotechnology would be successful in gaining funding? We find that both of these are true.

The general uncertainty created by the perceived lack of direction in national science and innovation policy is exacerbated by the uncertainty scientists face when applying for funding through national funding schemes (level 1 concepts: 2, 15, 22). Certainly with regards to the applied funding grant application process there is very little way of knowing what types of research will be funded or why some projects are selected (corroborated by various interviews).

As an example of the perceived lack of transparency and direction , presented below are two extracts from interviews:

“For fundamental research its absolutely fair, but for the applied research, the transparency of how they are evaluating nowadays, is not fair. We don’t know how they do it. And there are very mysterious calls about different topics, and we don’t know why some are getting funding and not the others”.

(Interview Ervin Balasz, 2006)

“It depends on the grant. This basic research grant, OTKA, this is perfectly transparent. This is the grant application we’re working on right now. We didn’t get the opinion of the reviewers and the only sentence they told us “this proposal does not belong to a sub task”. And this is not true. ...This is only an excuse, we don’t know what to change on the proposal. We tried to get more information, but failed.”

(Interview Hungarian scientist, 2006)

It may be expected that a lack of equipment would be the first indicator of economic struggles in the publicly funded research sector. This research finds that this isn’t always true. Observations make apparent the concentration of research resources in fewer centres such as in Szeged, Martonvasar and the ABC in Godollo, but these laboratories are well equipped and in good condition. There are strategic collaborations (see next chapter) both nationally and internationally which means that a lack of equipment rarely limits the activities of researchers (level 1 concepts: 7-10). There are however some complicated policies which create difficulties:

“Sometimes they tell us that we can apply for new instruments and they give the sum minimum. You cannot apply for anything if it is below this minimum amount. We can apply just for huge instruments and we have to participate in [contributing] 30%. But from where can we get this 30% for such huge instruments? And this is every year we can apply and we are supported by the state, but nobody gives us this 30% so finally we can apply neither for the huge instruments or for the small instruments.”

(Interview Hungarian Scientist, 2206)

Economic cutbacks and reductions in funding reverberate in the private sector. The university spin-offs, SMEs and public-private collaborations that might be part of a vibrant

research intensive innovation system simply don't exist. In some cases universities do not have the resources to invest in technology transfer departments and in other cases with a shrinking research sector, there is not the critical mass to allow spin offs to flourish. University spinoffs must form with either some service or product and customer base in mind. In the agricultural biotechnology research sector these are limited due to market uncertainty or lack of information about the market. This is only one contributing factor explaining the lack of this type of activity, the other is the lack of entrepreneurial culture which is elaborated in the next chapter (level 1 concepts: 2, 30).

6.2.3. The Politics of GM

In Hungary regulatory policy affects the private sector in a much more direct way than either the current lack of domestic market demand or the economic cut backs. The Gene Law has effectively prevented the commercial cultivation of any agricultural GMO and in addition, the government has also protested against the field testing of certain varieties such as MON810. The case was referred to the European environment council and the decision was upheld. Although it was an interpretation of the precautionary principle that allows national law to be formed in this way, I argue in this chapter that the root of uncertainty is less the cause of ambiguity at the European level, but more due to instability at the national level.

Seemingly decided, the stance taken by the national government should at least provide certainty in that Hungary does not, and will not allow GMO's to be part of its future. This would allow scientists faced with this certain outcome to employ their skills in other areas

and begin retraining for an alternative future. But national regulation is perceived as being incoherent and contestable. The nature of the decision making process itself throws a shadow on its ability to be stable over time. In contrast to European regulation which is perceived as being 'science based' and therefore stable, Hungarian regulatory processes and legislation are seen to be much more political in nature. As discussed above, regulation is subject to the influence of NGO's, farmers unions, and other politically motivated groups.

At the party level there are different possible approaches to the future of GMOs and GMO policy formation (level 1 concepts: 2, 20, 21, 23):

Researcher: *"Are NGOs successful in influencing politicians?"*

Dr Kasza Gyula: *"It depends on what the actual government is like. The conservative party is quite open to them and offered the Minister of Agriculture's chair for the leader of this collaboration. But this party has lost the elections. The socialist party, the leading power in the present government, doesn't put such an emphasis on them, they're quite apart from each other. One of the reasons for this distance keeping is their different views on Hungarian agriculture. This farmers collaboration would like to see a change in agriculture so that the emphasis is being put on small or family farms and companies while the socialist party supports concentrated firms with mass production in agriculture."*

The policy making process shows political in-fighting at the ministerial and committee levels. The competent authority for GMO's in Hungary is the Ministry for Agriculture. The

Ministry for the Environment has the power to veto any decision made, a power that it exercises fairly frequently (Professor Ervin Balazs, interview, 2006).

“Again the Minister of Agriculture wanted to make a kind of gesture to the opposition and created a 17 member group on co-existence. And out of those 17, 15 were organic growers, green organisations and two were the biotech association representatives, Professor Dudit and another guy, Professor Balazs from Martonvasar. At the time he worked for the Godollo biotech centre. Professor Balazs stood up at the first session because it was so hostile. ...So Professor Balazs decided to leave the group right away and the result came in the form of the most restrictive policy stance proposal – a 400m isolation distance.” (Interview, 2006)

There is also reported what might be called the politicisation of the science itself. Scientific evidence selected for the support of certain regulatory proposals is accused of being questionable and gained through less than an unbiased independent process of scientific investigation. There are reports that individuals or organisations which generate scientific results are prone to political pressure or the promise of funding in exchange for producing evidence supporting either one side or another (personal communication, September 2006).

Hungarian scientists criticise the national regulatory framework for not being sufficiently science based. They compare the national regulatory framework to that of the EU, praising the latter for what they see as a science-based regulatory system. However, Hungarian policy researchers say there is a lack of ‘sub-politics’ in the area of national GM regulation. In other words, the engagement of the public and the debate and discussion of policy at

regional and local levels. This may be a reflection of the top-down nature of policy making and in particular, regulatory policy making. Policy makers at the ministerial level placate the influential national groups and NGOs who are able to bring a great deal of media attention, in an effort to maintain votes but simultaneously demonise the EU. Regulatory policy appears to be a tool or political space that allows the government to control various groups with an eventual aim to win favour with the voting public. The development of sub politics, public debate, etc might weaken such control (level 1 concepts: 2, 20, 21, 23).

Jehlicka and Tickle (2004) predicted that CEE countries will become passively compliant with EU regulatory and governance requirements and their national perspectives will become eclipsed by EU hegemony. However, it is not the case that Hungary has simply chosen to passively accept EU direction in the area of agri-biotech regulation. Hungary has adopted a highly stringent form of EC regulation to meet its own ends, effectively and unexpectedly banning the commercialization of any GM crop in the country. Accession and the adoption of the *Acquis Communautaire* have not given national agri-biotech policy the predictability that might have been expected (level 1 concepts: 2, 20, 21, 23).

Regulation has differential impacts on innovation. For example in the energy industry, regulation often restricts the innovations that are possible but in the field of drug discovery, innovations are fewer where there is inadequate regulation and protection of intellectual property rights and patents. In Hungary in the field of agri-biotech it is less the regulation itself which is damaging to innovation, in some sense a narrow or strict regulation provides at least some direction to the path of innovation. But more damaging is the situation of the de-facto moratorium which creates a climate of uncertainty where those responsible for

investment in a technology or expertise become hesitant to commit to what would be a sunk cost. This has the effect that only certain actors remain in the innovation system – large multinational firms that can afford the sunk costs of investment and who can apply the findings of research from and in other countries, and public sector researchers who have the choice, at least in the short term of spending allocated funding in non-applied area's of agri-biotech (see later in the chapter). Smaller private firms or research groups are no longer able to stay in the innovation system (level 1 concepts: 2, 20, 21, 23, 30). I would theorise that because smaller firms are more closely connected with the domestic market, are more sensitive to uncertainty at the national level as argued previously on page 153.

6.3. The Future and Uncertainty as a Contextual Factor

One of the central tenets of NIS theory is that the national context and the country's specific history, economy and regulation shape the innovation system and its institutions. From the above discussion of the data, one specific factor of the national context emerges as being of significance. This is the relative uncertainty caused by the politics surrounding science and technology policy and policy on GM crops. Uncertainty relates to the future potential and use of an innovation in this field.

Rogers (1995) proposes that “technology is a means of uncertainty reduction that is made possible by information about the cause-effect relationships on which the technology is based” (p.13). From a starting point of identifying such cause-effect relationships we assume that an innovation to create a GM crop is a solution to a given problem. These problems may be for example the need to increase yields, to improve pest resistance,

drought resistance, to improve colour, texture or shelf life of a food. i.e. there is a cause or demand, which has an effect of the development of a solution. In this context, there is no clear cause or problem acknowledged by policy. Data shows that individual scientists act on what appears to be altruistic motives, or developing solutions to problems identified by others amongst their acquaintance (farmers or plant breeding centres who tell them of a disease), or they are guided by a trajectory of expertise in a certain area. The problems which they might identify are not widely agreed upon and do not exist in policy. There is a degree of uncertainty which therefore cannot be reduced since the causes are not agreed and innovation cannot be expected.

There are however a certain set of problems that policy at least at the EU level has demonstrated are necessary to solve. Detection, bio-safety, traceability, and labelling is one such example. Therefore, innovation in this direction can be expected and indeed, the success of the bio-safety centre at Martonvasar is certainly evidence of this occurring.

Time is an important concept in the study of innovation. Technology development with regards to the influence of path dependence has been discussed to some extent in the literature. For example Nelson and Winter state: “the condition of the industry in each time bears the seeds of its condition in the following period.” (Nelson and Winter 1982 cited by Antonelli, 1997). In this section I also draw attention to the role of future expectations as a source of uncertainty in the shaping of a trajectory.

The activities of innovators are in part determined by expectations of the future (level 1 concepts used: 2, 22, 25, 27). The relationship is similar to a demand-pull dynamic in that

relationships exist between innovators and expectations about the future environment. Activities, routines, accumulated knowledge, patterns of learning, are all adjusted according to expectation of not only the future market and demands, but also the demands of increased or altered regulation, expected changes in alternative, inclusive or complimentary technologies and so on.

In the field of agricultural biotechnology there are many examples of this. The trend towards molecularisation means that research institutions have to engage in learning activities. Activities that assist in the learning process include attending conferences, taking visiting research fellowship positions and engaging in collaborative research. Research institutes such as the PPI also carefully consider the balance of young and older researchers. This is a somewhat expected change based on a predictable long term trend. The changes in market demand and regulation which are effected by politics, are much more difficult to gage. Uncertainty becomes problematic and planning becomes much more short term (research observation notes).

In the long term, uncertainty and the lack of long term planning can have serious consequences for the future of a research organisation. If learning and knowledge accumulation is not accomplished, innovative potential will be damaged and the institute can fail to re-engage in the technological trajectory as it moves forward, leaving it stranded with outdated physical and human resources.

The research institutions examined in this study have developed various strategies in order to cope with uncertainty and environmental complexity. As the next section will show, the

strategy developed to cope with the various challenges of the context will have different consequences, so enabling the various complexities described above to be classified as more or less inhibitory to innovative potential.

6.4. Coping Strategies in the Hungarian Context

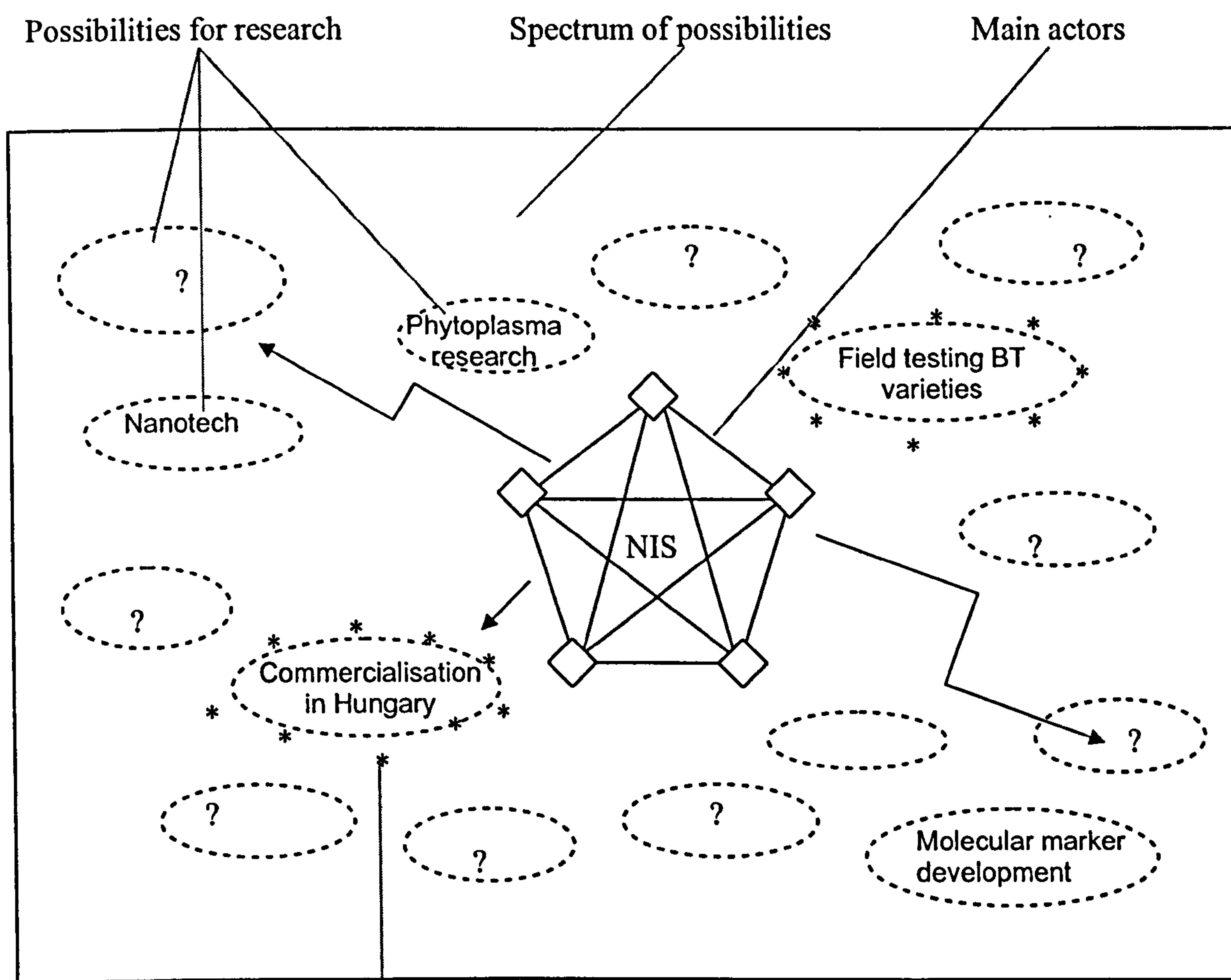
The agribiotech innovation system and the various actors of which it comprises, in an environment without restriction, would face a vast sea of opportunities, directions and possibilities. Uncertainty poses a restriction. The evidence above suggests that any of these uncertainty created restrictions are not and in some cases, are not perceived to be, permanent. It is possible to visualise particular directions and areas in this spectrum of innovation possibilities as ‘frozen’.

Figure 6 (next page) is a representation of the innovative actors and how one choice or direction may be chosen amongst others. Actors who are able to undertake activity are pictured as being within the webbed pentagram in the centre of the figure. Around them lies an entire spectrum of possibilities. Examples are given in the dashed ovals. However, due to national policy or otherwise, some of these possibilities maybe temporarily or permanently ‘frozen’ (indicated by *) so that actors are unable to access this research space. They may however redirect their attentions to alternative spaces.

The effects on the actors are differential. There are three main strategies. Actors may be unable to change their behaviour, possibly for reasons such as technological lock-in or a high degree of specialisation and so will either leave the system or look for markets outside

the system. Alternatively actors will adapt to the new conditions by changing their activities. And so the actors can either continue doing the same (and so they don't survive), continue doing the same, but outside Hungary, or do something different. The more detailed descriptions of strategies given in the rest of this chapter are subdivisions of this very general overall description.

Fig 6. Innovation Possibilities and Paths of Actors



An area of research or possibility that is 'frozen' and cannot be researched or developed

The data presents us with various examples of actor behaviour under the conditions of the complex Hungarian environment. Examining some cases in greater detail offers insights as to what motivates change and what allows adaptation.

Professor Ervin Balazs was a former director of the Agricultural Biotechnology Centre in Godollo. He began work in genetic engineering in the early 80's and has worked in France, India and South Africa. His realisation that Hungary at the time had very few protein and biochemistry engineers, which was the path the ABC was taking, led to the founding of a new research institute at Godollo in 2000. The aim was to develop a new line in environmental bio-safety research. The activities of the institute started with three divisions. The first was based on Ervin Balazs's own research interests, the development of new methods for detecting myco-toxins in animal feed and food. Second, a division to investigate whether food substances contain a GMO product, and a third division to investigate issues such as virus resistance and virus recombination. When asked what prompted this change in direction Balazs states:

“Because we had a very strong feeling that with this new technology, the public and society is quite eager to know whether this new technology has any impact on the environment and on human health”.

Founding a new centre was based on two guiding instincts. One, that existing human resources would eventually limit the scientific trajectory that was carrying forward the ABC. And two, a sense that public demand would result in a new service market in bio-safety to run in parallel to the development of new technology. Such planning and development requires considerable foresight and knowledge of the sector. What may assist

is an awareness of trajectories and trends in other countries. The development of a new division was also based on the accumulated knowledge and expertise gained in a specific field: developing methods for detecting myco-toxins. Success depended on being able to apply this skill to a new bio-safety market demand. Fundamental to such planning are key people who are experienced in the field and who have international connections. Also crucial is the ability to apply a foundation of knowledge in a new direction.

Such key figures illustrate the importance of the individual in the identification of potential pathways and dead ends in the formation of a trajectory (Nelson, 2007). Although these actors take on some of the functions of a network organiser, these individuals are not sufficiently linked to other organisations and actors such as would make them effective network organisers as defined by Radošević (1999). They are concentrated in the science system and are relatively upstream.

Ervin Balázs has since moved from Godollo to Martonvasar, the largest plant breeding institute in Hungary. He points out that in common with other research institutes there are two further trends occurring at Martonvasar. In response to the reduced funding, there is a move towards fundamental research rather than applied research. To conduct 'fundamental' or basic research is much less expensive, it has been suggested that it may be eight to ten times so. The ABC in Godollo although originally set up to work in applied science, similarly shows some movement back towards basic research, though for different reasons. The ABC has had for some time, a programme of research in potato. By transferring a yeast gene into the potato they were able to achieve a good degree of drought tolerance. Due to national regulation which prevents the commercialisation of GMOs, scientists at the ABC

have changed their research aims and outcomes. The aim is no longer to produce a drought tolerant variety, but they are using the variety they have produced to study the basic mechanisms of drought tolerance. They do this by comparing the drought tolerance they have created in their transgenic variety with the drought tolerance found in naturally tolerant wild species.

The ABC chose to launch this line of investigation and cope with the prevention of variety production in this way because it had accumulated a substantial body of knowledge following from a fairly natural trajectory in scientific investigation. The first work done on potato at the ABC looked at tuberisation. From this, the team began to look at the factors that effect tuberisation and found that sugars are important. From sugars they progressed to sugar sensing and then to drought tolerance. They predict that the next step will be research based on potato biodiversity. There is a path dependence that is exemplified here. In Chapter 3 Niosi (2002) demonstrates that human learning is one factor that creates path dependence. Organisations such as the ABC invest in the development of expertise and capabilities in this particular area which is a sunk cost of an intangible type.

This research on the basics of drought tolerance conducted by the ABC reflects the second trend outlined by Balazs: that the output of the innovation system is increasingly in the form of the production of new knowledge and understandings via journal articles, papers and so on. Using the metaphor of the sand-clock:

“The difference between the American and the European sand-clock? When in the American sand-clock one grain of sand is dropping, it produces one dollar.

In Europe it produces one paragraph.” (Interview Ervin Balazs, 2006)

And from the PPI in Budapest:

“The major output is papers. Scientific papers. But also with the breeding institutes, good collaboration, we cooperate to produce new resistant varieties, lines and so on.” (Interview Hungarian scientist, 2006)

This hints at a third type of activity taken forward by Hungarian research institutions: the production of new varieties via methods which are not perceived to be as harmful as genetic modification with foreign genes. The PPI would be working with breeding institutes to select on a genetic basis, lines which demonstrate particular required traits. The ABC in Godollo is simultaneously engaged in similar activity by including in their program of research, an investigation into drought tolerance as it occurs in wild species and beginning to accumulate a body of knowledge in this field. The ABC is also using its expertise to produce molecular markers. This is a tool used by scientists that can be applied to assist the process of classical breeding. It allows varieties with required traits to be selected from very basic samples of plant material without having to grow the plants and select the varieties much further down the line through simple observation. Molecular markers therefore vastly improve the efficiency of selection without producing a genetically modified plant. Dr Janos Balint at Corvinus University is similarly engaged in what he terms ‘soft gene technology’, the switching in or out of the plants own genes to alter function rather than the use of foreign DNA. He is explicit in the reasons for the direction:

“It is more acceptable for society or for green organisations...It’s a necessity because the European Union don’t want to accept gene technology in food science.”

A fourth option is to continue to develop transgenic plant varieties but with the aim of producing for markets outside Hungary. Many large research institutes are involved with collaborative research projects with international partners to continue work with transgenic varieties. The work may not be completed within the country or only a component part of the overall project might be allocated to Hungarian partners. Such collaborations require scientists to have knowledge of global trends and to participate in networks (see chapter 7).

A fifth new direction is gaining recognition. Actors are beginning to present GMOs as a solution to environmental problems. It is hoped that in this way public acceptance may be easier to achieve. Bioremediation is a growing market application for GMOs and a small number of Hungarian biotech firms are the first to see this as an opportunity. They seem to be particularly adept at marketing GMOs as a bioremediation solution to environmental problems and are ahead of the publicly funded research institutes in this respect.

Table 4 on page 174 summarises the coping strategies employed and the activities undertaken by the various actors discussed above. The effect of these adaptations are also given.

Table 4 draws comparisons between the impacts on the innovation system of different types of uncertainty. Regulatory uncertainty and lack of internal market both have the effect of changing the activities of research institutes in particular. Rather than providing a limit to their activities, this type of uncertainty alters their trajectory, motivating them to search in areas outside the 'frozen' spaces of the innovation spectrum of possibilities. If alternative activities are related closely enough to the original activities undertaken in terms of skill

usage and knowledge development, innovative potential is not lost, it is merely redeployed in other areas and there is the potential to re-engage in the original trajectory should it become a viable option in the future. However, this depends on how long the uncertainty will continue, as the increasing amount of time spent in alternative activities will create a permanent new trajectory as specialisms become established for example in bioremediation or molecular marker development. Similarly, returning to the practice of basic science and the publishing of papers sustains the possibility of re-engaging in the development of GMOs at some point in the future.

The economic crisis and funding shortages have the most permanent and damaging effects on the innovation system. It is not the infrastructure or equipment that suffers, as collaboration offers a solution to this. It is the closure of university departments over time that will gradually produce fewer scientists and in addition to brain drain, will further increase the generation gap. Uncertainty in funding is paradoxically the most certain thing as Hungarians are used to contextualising in the continuous debate over public spending and the economic crisis. As briefly mentioned above, the unexpected effect that funding uncertainty has had in this innovation system, is that it has forced the involvement of researchers and institutes in national and international research networks. Collaboration offers the opportunity for increased funding and Hungarian scientists with their stock of capabilities are successful in the development of collaborations and partnerships (see next chapter). This appears to be the only way that research institutions can circumvent the damaging effects of reduced government funding (level 1 concepts: 1, 2, 9-11, 29, 30).

Environmental Complexity	Main actors affected:	term uncertainty?	Actor adaptation strategy	Effect of adaptation on the actors
<p>Market Demand (the apparent rejection by the public, though the debate is highly polarised)</p> <p>And regulatory uncertainty</p>	<p>Down stream actors are highly effected by demand e.g. MNC's, biotech firms</p>	<p>It is a short term uncertainty, highly influenced by political trends at the national and international levels.</p>	<p>Actors perceive uncertainty as volatile, some publicly funded research institutes believe that GMO's will eventually be accepted and so do not change direction, but seek alternative global markets. They also develop alternative technologies e.g. molecular markers.</p>	<p>There is some change in trajectory towards alternatives for upstream actors – publishing papers, soft gene technology and complimentary technologies. Capabilities in the GMO area are continued and developed. Global networks developed.</p> <p>For down stream actors, particularly MNC's activity is completely prevented. Though since they are global players, they are not effected overall.</p> <p>Ties between upstream and downstream actors only temporarily disrupted – MNC's will not leave Hungary.</p>
<p>National policy uncertainty A)</p> <p>funding and the economic crisis</p>	<p>Publicly funded research institutes, HAS and universities</p>	<p>A long term uncertainty resulting from the past and will continue in the foreseeable future</p>	<p>Larger research institutes who are globally connected can avoid some loss of funding through collaboration and EU funding</p> <p>Universities and unconnected research institutes shrink over time</p>	<p>The university system suffers permanent damage through the loss of departments, equipment and scientists who go abroad.</p> <p>Where there are no international connections, lack of funding can gradually cripple the innovation system and permanently damage innovative potential.</p>
<p>National policy uncertainty B)</p> <p>Lack of direction in S&T policy</p>	<p>Research institutes and biotech firms</p>	<p>A short term uncertainty, related to economic development and government stability</p>	<p>The 'wait and see approach' is applied. Preliminary plans for bioethanol and bioremediation have been made but cannot be implemented</p>	<p>The innovation system slows as the direction is unsure. Investment is limited. No guidance given with national funding and actors follow their own trajectories as far as they are able to.</p>

6.5. Conclusion to Chapter 6

Lack of public demand for GM crops, uncertainty in funding and regulatory policy at the national and not EU level, are factors which are causing adaptation and coping strategies to be employed that will shape the innovation system in agri-biotech. The lack of funding clearly has damaging effects for a system so dependent on public funding. This is leading to the closing down of university biotechnology departments, the sale of government land, brain drain and the under-funding of key infrastructures such as university technology transfer departments. Over time this will lead to a shrinking of the innovation system as resources become more concentrated within the few well known large, state of the art facilities, such as the ABC in Godollo and the Bay Zoltan Foundation in Szeged. With the loss of smaller research groups, there is a loss of diversity in the areas of interest demonstrated by Hungarian agricultural biotechnologists. Any narrowing in the range of diversity, intuition tells us, is likely to result in a system that in the future will be less able to withstand significant change and shifts in demand.

The trend towards basic research, the publishing of scientific papers and so on, is one strategy that does not promote ties and connections within the actors of the system as well as would an applied research project. An applied research project would perhaps involve upstream actors who identify the practical problem, scientists and innovators who develop a solution, and downstream actors who would diffuse and distribute to a consumer or customer. The data viewed with this lens of coping strategies does not show a great deal of interdependence between actors, and in particular, down stream and up stream actors within

the national system. (The chapter which follows views the data from an alternative point of view and to some extent will contradict this statement).

The system seems to favour the 'key individuals' as the drivers of institutional change. Chapter 3 reviewed the work of Nelson (2007) who stated that innovation does not always follow a blind trajectory, but key individuals identify pathways, dead-ends and evaluate new technologies. This chapter provides evidence that this is happening in this study. While this is a good thing, the downside is that 'system learning' is not occurring to the same degree. Uncertainty, lack of funding and lack of direction in national regulatory policy does not allow for a stable environment in which such ties may be fostered with knowledge and innovations being developed across more than one organisation. In terms of the institutions that occur between the actors of the triple helix, what is seen is the isolation of organisations and the lack of co-evolution that triple helix dynamics would stress as important to innovation.

In an even more general way it might be noted that in the domain of basic research, within the directorship of key individuals or single organisations, the initial stages of investigation are carried forward by the interests and body of knowledge of the scientific team. It forms at first a fairly independent trajectory. However, as the science searches for an application, it becomes more exposed to legislation and is shaped increasingly by society and demand. I would suggest that it is more difficult to move from basic to applied research as has been attempted by large publicly funded, long existing organisations, than it would be for small private spinoff companies who are formed directly in response to a gap in the market and an unfulfilled demand.

The system as has been tested so far shows a remarkable degree of resilience. In response to research sub question 3, my evidence suggests that by employing strategies of specialisation in fields such as soft gene technology, complimentary technologies e.g. biomarkers, bio-safety and so on, researchers so far have generally been able to engage themselves in activities which will allow them to re-enter the field of agri-biotechnology at some point in the future and preserve innovative potential, provided that the innovation system does not deteriorate past a crucial point and the structure of the innovation system (in terms of the 'middle generation'), maintains a sufficient integrity. As chapter 3 showed, time matters not only because of uncertainty, but also because of irreversibility. Once key competences are lost, either through the loss of key individuals or otherwise, they will become difficult to replace.

Chapter 7: Networks as Institutions

7.1. Introduction

This chapter is the last of three data chapters which use data to analyse and explain how innovative potential is created and sustained amidst the change in the environment. Chapter 6 demonstrated the various coping strategies employed in order to survive the recent period of economic and regulatory change. That chapter concluded that some changes are in the long term, more damaging to the agri-biotech innovation system, and certain coping strategies are more effective than others in preserving innovative potential. This chapter will look at one particular strategy which is widely employed for various reasons, and which has the potential to assist in the long term adaptation and survival of the system as a whole: that of network building.

The chapter primarily forms a basis for answering research sub-question 1 on how the network of actors has evolved to accommodate the particular characteristics of agri-biotech, but also contributes to answering research sub-question 2 on the sustained use of institutional arrangements from the pre-transition era.

The chapter first provides an overview of linkages in the system taken from chapters 5 and 6 before discussing in further detail, the presence of networks and collaborations in the system. The chapter then goes on to analyse the effects, advantages and impacts of these networks and collaborations by analysis using two additional sources of literature that have not been used in previous chapters: communities of practice and epistemic culture. The

chapter concentrates primarily on the science community and in doing so, contributes to the understanding of the role of the science sector in innovation and transition.

7.1.1. Overview of Linkages in the System

There exists a vast array of institutional relationships between the actors in the Hungarian innovation system. Even by narrowing our focus in this chapter to the primary innovators in agri-biotech, i.e. the scientific community that is concerned with the development of new biotech solutions or products to new or old agricultural problems, still presents a picture of a highly complex system.

Broadly what we find are research centres in the main geographical regions where biotechnology is reputed to be clustered: Budapest, Godollo, Szeged and Debrecen, with other ‘stand-alone’ research centres in smaller towns e.g. Martonvasar (see chapter 5 for more detail of the actors involved). Laboratory heads and department heads from these institutes are linked to each other as well as to farmers, breeding centres, other government institutes such as plant protection stations, policy advisory committees etc. Laboratory heads are also members of international committees and collaborations with other labs based outside Hungary. Links can be formal as in official committee membership or informal such as the relationships which are sustained with ex-colleagues as projects come to an end. There are unclear connections with industry with the occasional material transfer agreements with large multi nationals, unofficial university based consultancies and legitimate spin-off companies. (various interviews, level 1 concepts used – 8-11, 30, confirmation gained). A small number of ‘bridging firms’ exist to assist the start up of spin-

offs and SMEs. These bridging firms are central to smaller satellite networks. In figure 5 this is represented by area a), see section 5.7.

Linkages may be strong or weak, they can in addition be dynamic, changing over time and are influenced by different environmental factors. To understand the full impact of the nature of these linkages with a view to shedding light on the concept of innovative potential, it is necessary to unpack and investigate in a micro analytical way rather than attempting simply to model the overall framework or to sketch the broad picture. The use of literature on communities of practice and epistemic cultures in the following sections are not featured in the literature review in chapter 3. They were sought and engaged with at a later stage in the data analysis as concepts emerged from the data in a grounded way.

7.2. Networks, Collaborations and Communities of Practice

A body of literature that provides in some way an entry point into this process is the writing on communities of practice (Lave and Wenger, 1991). A recent interpretation of this concept is given by Coakes and Clark:

“Groups of people who come together to share and learn from one another face to face and virtually, communities of practice are held together by a common interest in a body of knowledge and are driven by a desire and need to share problems, experiences, insights, templates, tools and best practices.” (Coakes and Clark, 2006. p92)

This broad definition at its surface easily describes the core parts of the networks observed in the Hungarian system. The scientific community is brought together by very strong

common interests: to make progress in understanding, to publish and to gain funding in order to survive (level 1 concepts used: 8-11, 12, 22). It is at this very primary layer of analysis that are found the first interwoven threads tying actors to their context and it is possible to observe how institutions both shape and are shaped by their environment.

The decline of national resources committed to science has resulted in a growing dependence on external sources of funding. The most important of which are European sources. These funding sources and in particular the European Framework Programmes, aim to promote the “European added value” (interview; Balazs, Sept 2006) and favour projects which promote co-operation between EU member states. (Level 1 concepts: 9, various interviews corroborate).

In addition to the resources spent by scientists in perfecting the application procedure, a significant amount of time and effort is dedicated to finding and securing international and especially European partners for collaboration. In many cases this has become a long but practised stepwise process. Initially acquaintances are made at conferences or one scientist is made aware of another’s work through various dissemination tactics (visiting fellowships, seminar presentations, conferences, publications). This is then pursued by more in-depth discussions on possible collaborative work projects based on the skills gaps perceived by each team. Finally there is a period of more intense negotiation to resolve budgets, training that may be required, division of labour and a general push from one side to increase enthusiasm and convince the other to make the time commitment. (Level 1 concepts: 9-11, 13, various interviews). This occurs prior to, and in preparation for writing a grant proposal, as exemplified by the following quote:

“I will go to Germany to try to organise a team to make a proposal for the European Union for biological control against phytoplasma diseases... We want to make a common proposal in the next European scientific framework which will be ... this autumn or the beginning of the next year and we are making some efforts already to write the proposal. So next week I will go to Germany, in the summer I visited Italy. I tried to make contact with those people who are interested... Generally many people are interested, but when you ask them to make a concrete proposal, sometimes they are very short, just a few lines, they will not have a good idea of how to do it. It takes time to convince them and somehow to divide the work and to put those things together at a logical level.” (Hungarian scientist, Sept 2006)

“Now I’m working on another proposal together with people from Switzerland, Germany and also from South America – from Peru. In Lima there is the largest potato breeding centre. So we will try to make a project together. And maybe it can be successful, that can give good support for the lab in 2008 I suppose because it will take a year. It’s a long procedure, the evaluation, the negotiation and everything.” (Hungarian scientist, Sept 2006)

Clearly a useful instrument in the initial matching of partners is the organisation of events which aim to disseminate and publicise the work undertaken in different laboratories (level 1 concepts: 9 and 10). International conferences such as the Plant Resistance Symposium in Budapest, attended by over 300 people, was at once broad in terms of international connections whilst maintaining a special platform for Hungarian scientists. Against a particularly elegant backdrop of the Hungarian Academy of Sciences, the symposium

attracted a prestigious list of renowned speakers. Yet it was a first in many years in Hungary while informal discussions made clear to me that such events, and larger besides, were not unusual in other countries (research observations September and October 2006). It may seem an obvious step for government to engage in the process of networking and attempt to assist. However as the quote below reveals, government initiatives have failed in the past.

“Now there is a Hungarian office that can help to find partners for EU projects, but I don’t know how many partners they could find because for me they never worked, I mean we know each other, we know each others work from publications. So we know how we can fit to each other and somebody who is not familiar with the work, I don’t know. They ask us to fill up certain forms, give key words, but it doesn’t help as much as going to a conference to look at a poster and you find that ‘oh, this is related to my project, lets find these people, talk to them’. It helps much more than an office that tries to match you with partners just based on key words, I don’t like it very much.”
(Hungarian Scientist, Sept 2006)

“All scientists visit meetings once a year or twice a year, they have more grant money. Usually, personally, I only visit one conference a year. And we have established more contacts in Germany, Austria, Spain”. (Interview, Hungarian Scientist, Sept 2006)

Part of the infrastructure important in facilitating the formation of links are the communication technologies. The increasing use of the internet and email are important to

scientists (level 1 concept: 21, triangulated by several interviews). This is exemplified by the following two interview extracts:

“And you know, nowadays, even if you don’t know someone, you just type his name in Google, see his publication list and from his publications you will know what is his direction in science.” (Interview; Balazs, Sept 2006)

“What’s a really big change, you know, personally, this is the computer and the internet. Its changed so much the science and the library need. To organise this symposium was also much easier and faster”. (Interview, Hungarian Scientist, Sept 2006)

7.2.1. From Networks to Collaboration

From the initiation of a contact and the formation of a network, the next stage is a partnership more committed to a given project with a predicted outcome, defined goals, agreed rights and responsibilities, a commitment of dedicated resources and a timetable. In other words, a collaboration. Collaborations are far more engaged and interdependent than a network although they are often formed from them. A sub-community perhaps. Every institute visited, while being part of a greater network or community held together loosely by common knowledge’s and practices, was engaged in at least one, if not more, collaborations of a much more intense and purposeful nature with domestic and international partners (level 1 concepts: 8-11, research observations and various interviews). The agricultural biotechnology centre in Godollo for example, is actually

working with institutes in the Netherlands and Germany on Potato varieties. To understand why collaborations are formed and what allows them to become successful, it is possible to draw upon field data for another example. The Plant Protection Institute in Budapest attempted to foster a collaborative effort with partnering institutes in China. Unfortunately there are no significant practical problems common to both agricultural contexts that would have engaged both sides, and so attempts failed. However, collaborative efforts were successfully promoted with Cornell University in the US because the US shares plant diseases in common with Hungary. For this same reason the PPI is finding similar success with European partners in order to combat phytoplasma diseases, a widespread problem throughout the continent. So again the unifying factor centre to the creation of a community or network is a common interest or common problem.

7.2.2. Learning in Communities of Practice

The literature on communities of practice originates from the works of Lave and Wenger (1991), the principle of learning. Lave and Wenger writing in the early 1990's explored the concept of legitimate peripheral participation. This theory describes how a new member of a community becomes a more experienced member by first engaging in simple peripheral but nevertheless important tasks. In doing so they gain an understanding of the organizing principles of the community, its vocabulary and its culture.

Table 5: Key characteristics of a Community of Practice

Key characteristics of a community of practice
<ul style="list-style-type: none">• Sustained mutual relationships – harmonious or conflictual.• Shared ways of engaging in doing things together.• The rapid flow of information and propagation of innovation.• Absence of introductory preambles, as if conversations and interactions were merely the continuation of an ongoing process.• Very quick setup of a problem to be discussed.• Substantial overlap in participants description of who belongs.• Knowing what others know, what they can do, and how they contribute to an enterprise.• Mutually defining identities.• The ability to assess the appropriateness of actions and products.• Specific tools, representations, and other artifacts.• Local lore, shared stories, inside jokes, knowing laughter.• Jargon and shortcuts to communication as well as the ease of producing new ones.• Certain styles recognized as displaying membership.• A shared discourse reflecting a certain perspective on the world.

Amin and Roberts (2008)

The concepts of legitimate peripheral participation and learning are important in the discussion of innovative capability in Hungary. To innovate in agricultural biotechnology requires an understanding of a body of scientific knowledge and scientific practice which must be learned. To understand the effects of the context on the practice of learning, for example government policy, the structure of the innovation system, fiscal austerity measures, the generation gap (discussed in previous chapters) etc., a better understanding of learning by innovators in the agri-biotech system is well placed here.

First it is necessary to ask the question of whether it is appropriate to apply the concept of situated learning that is so central to Lave and Wengers work. Although a vast amount of theory and basic practice is taught at the university level, it is clear that the practice needed to perform in the laboratories which contribute to Hungarian innovative capability, is

learned in the very same laboratories. All four centres considered by the fieldwork found that laboratory leaders were keen to select and train PhD students. Students considered themselves privileged and lucky to gain one of the few places offered every few years to complete their PhD projects under the tutorship of these major centres. And for the research centres, the preliminary results they need to put forward for research proposals, as well as the more routine lab work, can be done more effectively via student projects (level 1 concepts: 18, 8, 13, 18, corroborated by various interviews). This is exemplified by the following quotes referring to the grants given by the NKTH and the role of students:

Scientist: *"Without promising a good result, you cannot get the project. So you always try to propose such a study which is at an advanced stage. Of course to get to an advanced stage, you have to have made several preliminary experiments ...so this is a problem. The maximum period of time you can get a project for is four years."*

Researcher: *"And how do you fund the preliminary experiments to get to the advanced stages?"*

Scientist: *"It's parallel and unofficially. We have some students and we give topics, projects for the students and we try to support them from their other projects"*

(Interview, Hungarian Scientist, Sept 2006)

Another laboratory head:

"So this is the project of the group and here we work 7 together. I work with PhD students mainly. A post doc is in the lab but all the others are PhD students ... they are students at the university, so they get their lectures there but they do their practical work here in the lab."

“The institute you will see is a relatively good institute and when we have foreign visitors they also recognise that that we have very good infrastructure so we are quite well equipped. And this is not usual in Hungary, especially in agricultural research, so those interested in agricultural research, biotechnology and would like to get a PhD, come here. So it was not difficult to get PhD students... This institute belongs to the Agricultural Ministry so we are not an academic research centre. Our research projects are more applied than fundamental so we are closer to the practice than to fundamental research but its still not automatic what we do, we really have to think a lot. So its good for students also because they can get practice in a lot of techniques.”

(Interview, Hungarian Scientist, Sept 2006)

And of the students of the above mentioned team:

St1: “I’m making my PhD here. I’m a chemist. I’m doing some analytical things with GCMS³³ and from fruits, plants or anything, I measure metabolites. Secondary metabolites and so on. I think this is a good opportunity here in Hungary so I have many opportunities. I can go further with many work places with this thing.

Researcher: “And are you an expert with this equipment now?”

St1: “I don’t think I’m such an expert, but I learn a lot and I can use it, so I will be an expert within a few years I think. And the other thing is, it is very hard to get the information, the techniques...so two or three labs and this is good because there is not much competition, but its hard to learn”

³³ GCMS: Gas Chromatography Mass Spectrometry

Learning appears to be important for the student also. They perceive it as one strategy to become an 'expert' in the field and marketable in terms of job skills, particularly in gaining familiarity with laboratory equipment which can only be found in the larger well known research centres. There is the presence of a scientific lineage in Hungary with many of the laboratory heads interviewed associating themselves as students or colleagues of very well known scientists of an older generation or with their labs. This implies that some skills can only be learned whilst working in leading labs or with pioneering people (research observations, September and October 2006). Learning within the laboratory setting is important too due to the nature of science and the protocols which become established. This is discussed later in the chapter with reference to epistemic culture.

Having established that situated learning is both an appropriate concept and valuable to the actors described above, referring back to Lave and Wenger's work reveals why situated learning plays a crucial part in sustaining innovative capability. Lave and Wenger's work is in part a critique of previous studies of learning, which place internalisation as a central concept. This focus on internalisation whereby a learner internalises knowledge whether discovered, transmitted by others or gained through experience, it is argued by these authors, does not significantly consider the outside environment of the learner, nor the institutional relationships they hold with the outside world. This prior work mainly frames learning as a problem for the individual and a process of absorbing and assimilating given information.

Partial headway seems to have been made in the late 70s and 1980s with interpretations of Vygotsky's work on zones of proximal development. For example; a scaffolding

interpretation suggests that this zone might be characterised as the distance between the problem solving abilities of an individual working alone and that individuals same abilities when assisted by those more experienced. A second more ‘cultural’ interpretation as carried forward by Davydov and Markova (1983) and Hedegaard (1988) suggest that the zone is defined as the distance between cultural knowledge provided by the socio-historic context and the everyday experience of the individual, with information and knowledge from the former being made accessible via the process of instruction (Lave and Wenger, 1991).

Lave and Wenger place yet more emphasis on the importance of the social world and in contrast to internalisation learning is seen as a product of participation in a community of practice. It is dependent on the individual continuously renewing his or her set of relations with their context and situation. They state that learning and experience are in constant interaction and that learning results in the transformation and change of people.

And from this initial work, a later version of Wenger’s work in 2001:

“Communities of practice are a specific kind of community. They are focused on a domain of knowledge and over time accumulate expertise in this domain. They develop shared practice by interacting around problems, solutions, insights, and building a common store of knowledge” Cited by Coakes and Clark, 2006, p92

As the communities of practice literature has gained focus over time, it has attracted much attention from business scholars and has been developed as a strategy to grow and manage knowledge as an asset. The increasing complexity in products, process and services required much higher levels of specialisation and collaboration between workers (Archer,

2006). Although not explicit, authors such as Archer have developed the idea of communities of practice as something more structured within an organisation where knowledge management, learning and transfer can occur but require motivation and co-ordination through codified channels which the community and organisation provides. Coakes and Clark likewise imply particular use within organisation suggesting that the work of an organisation can be facilitated or frustrated by such communities of practice and for communities of practice to succeed they must not be over-regulated or under-structured.

The activities described which contribute to creating the community of practice are summarised in table 6.

Table 6: Summary Table of Activities Contributing to the Community of Practice

Activity or Common Goal	The Common Aim, Shared Problem, Experience, Tool or Best Practice
Joint research project between two actors	To jointly produce new knowledge
	To identify a new problem common to both parties or to develop a new solution which can be used by both parties
	To publish
	To write proposals and gain funding to support themselves
Joint events (e.g. conferences)	To make further connections with other actors
	To disseminate and make others aware of your work, and to absorb knowledge about the work of others
Visiting fellowships / seminar presentations	To learn and share new knowledge, protocols, best practice
Accommodating PhD students into research programs	To transmit knowledge, protocols and best practice from one generation to the other

The column on the left identifies the goal of the actors involved in any particular activity and the column on the right shows what each party aims to commonly accomplish. There are however, various activities which serve the interests of both, but which provide asymmetric benefits. For example, accommodating PhD students within research programmes also has the aim for the centre of advancing research proposals, and for the student, they wish to gain marketable experience and complete their PhDs (see discussion above). These goals are not shared by both parties, but the activity is to the benefit of both. Other activities are similar in this way, for example, teaching, sitting on evaluation or policy committees, participating as an expert as part of an international body (EU). These types of connection are further discussed below and are better described as networks since they are not in the strict sense, a shared and commonly developed experience as defined by community of practice.

7.2.3. Communities of Practice as an Inadequate Description of Networks

The networks and collaborations are complex. Often they extend internationally. Scientists and students in Hungary maintain contacts with former colleagues and classmates. The success of the symposium and the ability to attract so many “big names” was partly attributable to connections maintained with expat networks. Many of these former classmates and colleagues within the field of plant science have since left Hungary for destinations such as the US but they remain important channels for information, collaborative work and other opportunities. The channeling of information is absolutely vital to the survival of the innovation system as a whole and for developing the collaborations that create communities of practice.

With respect to offering a full description of the networked innovation system in Hungary, we find that the communities of practice literature though it provides some explanation and insight for the core competencies of the network, is inadequate as a tool for explaining many of the other dynamics which may be overlooked but are nevertheless important for the survival of the innovation system. The networks are complex and cross boundaries, not only internationally as described previously but also between various actor groups who have a contribution in the innovation system. The points at which networks are extended beyond the generally accepted meaning of community of practice are as follows (level 1 concepts used 8-11):

a) As mentioned in previous chapters, research centres are linked to universities through various research and teaching programmes. The linkages are not as integrated as would be expected in the Humboltian model (see chapter 3), however some connections prove to be advantageous. Universities are influenced at least to some extent by the work of research centres or groups. Teaching programmes thus become more useful, more focused and relevant to research. The communities of practice literature fails here to capture the assymetric benefits gained by students who absorb knowledge and centre researchers who supplement incomes, use university facilities and promote their research to potential PhD students.

b) Many well regarded plant scientists act as reviewers for international journals, they sit on international bio-safety committees for organisations such as the OECD, the EU (European Research Council, the Cartagena Bureau, the UN (UNIDO) etc., thus furthering the extent of scientific networks. These international committees do contain other scientists often working in similar ways and in similar fields, however, the committees are not brought

together in a sustained way in order to create knowledge, to learn from and co-define the other members of the group. The committees often contain of temporary memberships with members also coming from other areas (e.g. govt bodies, policy or administration.) However, they do further the extent of networks (Brown and Duguid,1991, cited by Amin and Roberts, 2008) allowing informal relationships to be formed and useful information to be transmitted (Granovetter, 1973).

c) Connections are also formed when not only scientists, but PhD students also take up visiting fellowship positions. Such visits are not restricted to Hungarian nationals travelling abroad, but also though less frequently, do international visitors spend time in the laboratories of Hungarian research centres. At the time of field work, the Plant Protection Institute had visiting students from Romania and Egypt and visiting researchers from Romania, Slovakia and Serbia. Meeting with the Egyptian student, the extent of connections were revealed. His supervisor was a German PhD where he was permanently based in Berlin and an ex-colleague (having previously been involved in a collaborative project) of a senior figure within the PPI. Here, the community of practice literature does not describe adequately the possibly wide geographical spread of participants that can still engage for a short time and leave to extend the network.

d) In something similar to a 'production chain', connections exist between innovators and those higher up and further down the production chain. Expertise and disciplinary fields are related but are not the same as a community of practice would imply. For example, the PPI has connections with plant protection stations in many other European countries and also with the plant protection and agro-chemistry network set up by the Ministry of Agriculture in Hungary. This network acted as an early warning system, alerting scientists to agricultural pest problems. Unfortunately many of these advantageous connections have

been lost through the government downsizing the Hungarian Plant Protection Stations. The links further down the production chain have a similar function. The PPI is connected with the Potato Breeding Institute in the University of Veszprem and the large classical breeding centres such as that near Lake Balaton in Keszthely. Both the ABC in Godollo and the PPI in Budapest use classical breeding centres to test GMO's in field conditions. The following quote from MArtonvasar illustrates how connections that are commonly formed with breeding institutes or research stations:

“Well we did develop this plant in Godollo but went to the largest potato breeding institute which is near Lake Balaton – that’s in Keszthely. Or I had tobacco for 10 years in field conditions. That was in Debrecen where the tobacco research station is. So this is one of the disadvantages to Godollo in that it is quite isolated. It has no fields. This is an advantage for this institute because we have fields to do field experiments. So we have transgenic wheat in field conditions, we’ll have transgenic corn in the future. We can create field conditions on our field plot. But Godollo has no field so it has to work with different breeding institutes which is not bad in some sense because you have the best access to the good breeders. We have just been on Tuesday in Kalocsa. Kalocsa is the place where we have the pepper breeding institute ... so we have virus resistant pepper and other kinds of multi-resistant lines made either by conventional breeding or marker assisted breeding or by genetic engineering and now we are working with Kalocsa to do field experiments.”

(Interview; Balazs, Sept 2006)

The classical breeding centres, due to their expertise and also their geographical location, are able to provide information on the most current pest problems (though this information is passed through the network via informal acquaintances). Some direct contact is made with farmers however this is far more infrequent and impromptu;

“We are talking with breeders and farmers are coming and telling us ‘this is the problem’. We have practical journals, plant protection periodicals, a weekly magazine on Hungarian agriculture, and we just see the news and see that this is the problem. And an outbreak of a new epidemic, talking with the Plant Protection people, it’s a cross talk lets say.” (Interview; Balazs, Sept 2006)

The PPI organises some scientific meetings in the countryside. About this the following was said:

Scientist: *“You know that meetings in the countryside. There are more practical interests there. There are many people who don’t speak, they are just sitting there and they want to apply the results.”*

Researcher: *“These would be companies?”*

Scientist: *“No, not companies, farmers. ...There are many private, not really companies but private farmers so they have several workers and so the leader is scientifically based and he is going to meetings and he is just a manager looking for new approaches.”* (Hungarian Scientist, Sept 2006)

And later:

Researcher: *“So the results that you produce, where do they go? Who is your audience?”*

Scientist: *“Well scientists first of all and then as I mentioned we have direct contact with farmers. So especially in diagnostics. So this is another respect which is not supported by the government but we have direct contact with farmers from time to time, they come to advise us what to do. So I think this is the best solution.”*

Researcher: *“How do they know you exist for them to come to you?”*

Scientist: *“Yes you are right, this is not easy. I am relatively old man and so not the farmers, the intermediary people working in the Plant Protection Service or at the University, so they know I work with Phytoplasma. So if there is any problem in this country with the phytoplasma, then the problem comes to me. And we write papers for farmers as well.”*

Researcher: *“For journals and magazines?”*

Scientist: *“Yes, so every year one or two such papers we write. But there is luck – topics you know, we should have much more contact.”*

7.3. Advantages of Networks in the Hungarian Agri-Biotech System

There has been substantial work on the idea of networks as similar institutional patterns have been found whose description and advantages extend beyond communities of practice. For example Brown and Duguid (1991, cited by Amin and Roberts, 2008) develop the definition of ‘networks of practice’. This is an informal emergent network created by set of individuals who are connected through social relationships. Relations between group members are looser than in a community of practice. Williams (2002) has described the

activities of ‘competent boundary spanners ‘ in inter-organisational management. These types of networking activities are found in Hungary and are described below in terms of the advantages they confer to the system. Section 7.4. goes on to describe yet one more type of network activity based on Knorr Cetina’s (1999) concept of epistemic community, which is very similar to a community of practice, but goes further in explaining the process of situated learning in the laboratory setting.

There are distinct advantages and possibilities created by cross boundary networks that exist beyond a single organisation or even a single disciplinary group or community of practice.

Firstly, and importantly in a resource constrained system, contacts and collaborative efforts offer access to more or better physical resources e.g. instrumentation and facilities such as field space. Of course the partnering institution should have some asset worth the trade, and in the case of Hungarian laboratory research centres, these are often in the form of superior knowledge expertise, specialised labour and project management skills (level 1 concepts used: 9, 10, 13, various interviews).

Secondly, as indicated by Balazs, connections with classical breeding institutes created the opportunity to work with the best classical breeders. So there is the advantage of gaining access to additional human resources which have alternative skill sets and different expertise. In the biological sciences, history has occasionally illustrated that a mixture of expertise or interdisciplinary teamwork can provide the solutions to problems that might otherwise escape the narrowly focused individual. For example, the relationship between

dominant and recessive alleles was puzzled over by the geneticist Reginald Punnett in 1908. Unable to find an expression for the general relationship, he introduced the problem to G.H.Hardy a friend working in Mathematics also at Cambridge with whom he played cricket. The p^2+pq+q^2 mathematical expression (later known as the Hardy-Weinburg principle) seemed obvious and simple to an advanced mathematician such as Hardy.

The point to be made here is that it is not necessarily the formality of the link which is significant. Weak links can be equally as significant if they have the potential to reach further into an unknown territory. This study's own data demonstrates much the same. Friendships and acquaintances prove to be advantageous for future collaboration, information or resource sharing projects. This is particularly the case in Szeged where the number of spin-off companies is higher than usual. These small independent companies were started by ex-employees of the Biological Research Centre, the main biological research institute in the region. As a result the study found that some CEOs were quite well acquainted with others, even though they had taken different paths in terms of specialisation, often referring to each other as 'good friends'.

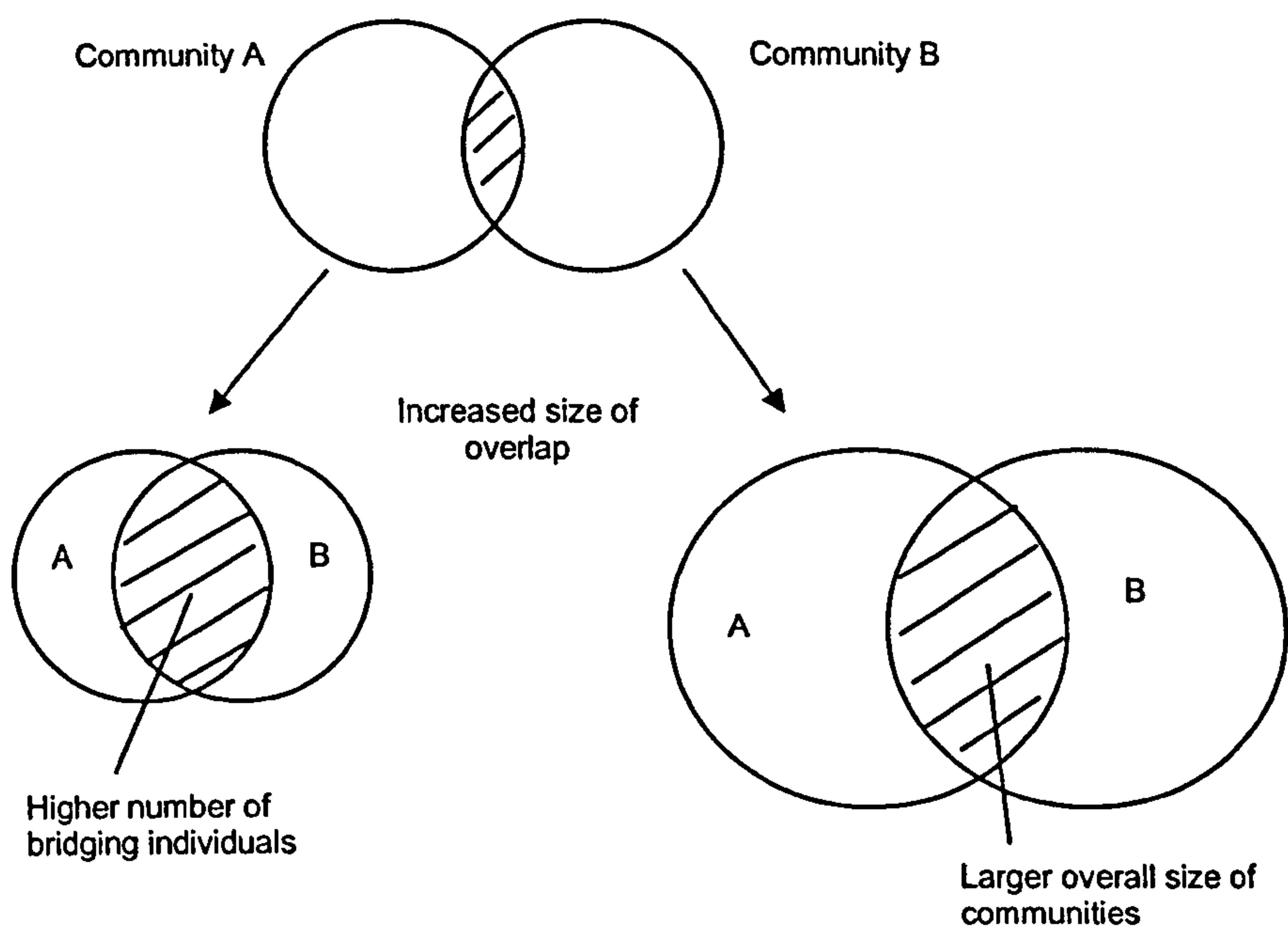
Thirdly, we might consider the importance of being able to bridge the divide between two communities of practice or two networks. The following extract in this case describes two networks. Fieldwork did not investigate the situation described, so it is difficult to tell whether they are actually communities of practice, or whether the individuals are less closely bound in something that would better be described as networks of practice. In any case the point to made here is that bridging occurred, possibly through the use of boundary

spanners which allowed ties to be formed between the two networks or communities and for information to flow between them.

“Maybe I’ll tell you this story that we had a new pear production in Hungary. This is originated from Italy. And in the science we didn’t know that but the farmers visited Italy so they had a so-called intensive pear cultivation method. That means they used small trees and irrigation and the plants are very productive. So they started with plant material originating from Italy and many of them were phytoplasma infected. The disease is much more serious in Italy than in Hungary ... And even they have advisors from Italy from some of the big companies from Italy, they have some kind of connection with the Hungarian farmers and every month advisors from Italy come to Hungary and tell what to spray and how to do and so this is an interesting connection... this is new, and it was a surprise even for me that independently from all kind of official organisation, they went to Italy and the advisors came to Hungary.” (Hungarian Scientist, Sept 2006)

This work has shown and will show in section 7.4. that both communities of practice and broader networks of practice exist in the Hungarian biotech system. If bridging contacts or ‘boundary spanners’ (Williams, 2002) exist between the communities and networks, they may be mutually reinforcing. The extent to which they are reinforcing depends on i) the number of bridging contacts or ii) the size of the network and variety of individuals within it and therefore its outreach to potential other communities. This theoretical proposition drawn from the observations made during fieldwork is graphically represented by fig.7

Figure 7: Critical area of mutually reinforcing communities of practice



Fourthly, widespread network connections can help to achieve dissemination of research and promote the expertise and reputation of a research centre or an individual scientist. As the extract above shows, knowledge of his reputation with working on phytoplasma diseases ensured the channeling of certain relevant information.

Fifth, the filtering, channeling and outreach of information is important at numerous levels. The previously mentioned ‘early warning system’ alerted scientists to potential real problems in the field. Contacts with those sitting on EU committees can pass down information on the type of proposal likely to gain EU funding. Colleagues based internationally can help to give a perspective on the general trends in global biotechnology development. Connections and access to information assist in contingency planning or

formation of coping strategies when changes in direction or broadening of portfolios are required (see previous chapter). Such information reduces risk during this process (level 1 concepts used: 2, 9).

Finally, in consideration of the above points, broad based interdisciplinary networks assist in the learning process which must occur when there are big shifts in the trajectory or culture of science (level 1 concept used: 22). This point requires somewhat detailed discussion of epistemic cultures and further reference to fieldwork data and so will be continued in the next section following a brief discussion of the problems of discontinuity in networks which will conclude this section.

Clearly there are discontinuities in the networks which prevent the flow of information, cause the increase of risk, create the blindness of trajectories without the context of the wider international community being connected with, prevent the learning of new techniques, procedures etc. Isolation of a community can indeed be a dangerous thing. These discontinuities in Hungary have been caused by the shrinking of sectors, the loss of jobs and closing down of institutes which occurred mostly just after the transitional phase (level 1 concepts used: 1-3, 8).

A major example in Hungary is the break in link between the chemical industry and plant sciences through the production of herbicides and pesticides:

B: "So what has been lost I would say, as I mentioned we had especially the chemistry department – very good contact and the herbicide department, many I

would say small grants from the chemical industry for pesticides. Now I would say it's not at all."

Researcher: *"Why is this?"*

B: *"Mainly because all the Hungarian pharmaceutical and chemical factories are bought by western multinationals and then – "*

G: *"They don't want Hungarian research, they have some centre in ..."*

B: *"And as far as I know there is not much pesticide production in Hungary. The whole industry collapsed after these big changes in 1990. Simply they have no money or chemical research".* (Interview: two Hungarian scientists, September 2006)

There has been the loss of linkages but also there is a specific lack of creation of particular bridging institutions that other national innovation systems beneficially have. These bridging institutions are for example initiatives, projects and organisations which link the scientific community closer to practice and to the practical application of their work. In fact the network seems as if it is only being situated on the former strengths of the older generation of scientists and the reputation and contacts they have built over time (research observations and various interviews). (It may be useful to note here that European networks existed before entry to the EU in 2004. Accession did not help or change the situation, in terms of science Hungary has been a full member of all the relevant networks in Europe well before becoming a full member of the EU).

This leads us to the next very important point regarding the link between research centres and private industry. Private industry in plant science is characterised by a low number of small firms and the presence of some large multinationals. On the surface there is

practically no contact between scientific research undertaken by government research centres such as the PPI and the ABC, and the large multinationals (level 1 concept: 24, 30). The lack of contact with this type of private industry is perceived by both sides as caused by a lack of motivation from the other. Large multinationals accuse government scientists as only being interested in basic and not applied research and government scientists report that large multinationals are not interested in Hungarian research or Hungarian plant varieties (see previous chapter). The history of this break up is long and complicated with each side denying connection and intent on blaming the other. Martonvasar has a material transfer agreement with Monsanto for one event, but this was the only connection admitted to. In principle research centres say they would like to develop a partnership (several interviews 2006, 2007).

Despite this apparent lack of connection between public and private sectors, interview data and informal discussions point to the existence of consultancies associated with university professors. These small, often family owned and run ‘consultancy’ businesses are unlikely to be admitted to. The activities which may be lab based are reported to be carried out with university facilities and are deemed by the universities as a misuse of their resources. The following interview extract reveals this (corroborated by another interview).

H: *“The other area is the research and development activity of the university which also belongs to me as vice rector. I recognised that most of the professors, meanwhile they are professors (appointed to this nice position by the president of the country), they have a small personal firm. You know what it is? A small company, maybe only himself or his family are working in it. If such professors have a research or*

development activity, and get some money support, they transfer this activity into that firm. And I thought this was a problem. You have to bring the money to the university if you are a professor of that university and not to your company ... these small private companies have a risk to the future of the university”

Researcher: *“and what do these companies do?”*

H: *“If they have a small firm and they are asked to give an experts opinion on whether this power station will be placed here or there and he will give his opinion, I don’t know how is it called?”*

Researcher: *“Consultancy?”*

H: *“Consultancy and so on and so on. And he will get the money, not as a professor of the university, but the owner of the company. These professors pay nothing to the university for using the laboratory, the computer system or the knowledge or the infrastructure they use.”*

Researcher: *“And does this happen with people in plant sciences?”*

H: *“Everywhere”*

Researcher: *“So the use university facilities?”*

H: *“Of course. You cannot make a difference because this is his profession. How you can control him, if he is working under the microscope. What is that – teaching, education, academic research or his business activity? Nobody can control.”*

H: *“If we discover something new in biotechnology we will publish it, because this is a request from the grant owners who supported that research and important for the scientific careers of the researchers. Sometimes we can patent some of our results but we cannot make sale-able biotechnology products, because we don’t have the capital*

needed for that. Big seed companies can buy the results, but here in Eastern Europe they can buy it on the black market too. Nobody can control Eastern European researchers who work in state institutions for a miserably low salary.” (Interview: Professor Laszlo Hornok, September 2006)

These hidden consultancies may be frowned upon by the universities and the reported black market sale of discoveries to seed companies does have a sinister tone. However, they do extend the science networks into the world of industry and indicate the possibility of further innovative activity disguised from public statistics.

7.4. Epistemic Cultures, Learning and Trajectories

In a lecture critiquing political economic theory, delivered in 2005, Douglas North said that culture is an important factor which has largely been ignored. It's an important part of the real world because it firstly creates path dependency by constraining the choice set available. And secondly it creates trajectories. In other words, “we need to understand where they've been to understand where they're going”³⁴

Communities of practice and Lave and Wenger's concept of situated learning, go some way towards exploring the institutional relationships within the innovative network, but a deeper understanding is gained by explaining how an epistemic culture and the institutions it creates, underpins learning, extended networks and communities of practice. It will therefore shed light on the kind of adaptation which must occur when the system undergoes change as it invariably must.

³⁴ Douglas North, lecture delivered at Hertfordshire University, 12th May 2005

7.4.1. Cultural Variation across Scientific Communities

Is it possible to describe the innovation system network in Hungary and the main innovators as having such a common culture? Work by Karin Knorr Cetina compares and contrasts the cultures of two different scientific disciplines: high energy physics and molecular biology. In both and as a generalisation of the world of scientific laboratories, Knorr Cetina explains that the laboratory has reconfigured around it, a social order of its own. ‘Laboratorisation’ started at the turn of the century with medical sciences being transferred from the bedside to the clinic. Generally by the detachment of nature and the ability to manipulate conditions, an epistemic culture with its own language, procedures and codes of behaviour has gradually since then evolved. Now we see laboratories as “social and political structures that ‘belong’ to their heads in the sense that they are attributed to them and identified with them” (Knorr Cetina 2003).

Knorr Cetina goes to considerable effort to differentiate between the cultures of the two scientific disciplines in her study. For example the ‘life-time’ of experiments. In high energy physics, from birth to conclusion, a project may run for 20 years, whereas in molecular biology, it may be just a fraction of that time. The facilities and workforce required to complete a project in high energy physics is correspondingly also much larger than that of molecular biology. The result of these variations is a substantial difference in the organisation and culture of the communities. In high energy physics there is a tendency to move away from centralisation and the work of individuals. Experiments and publications are undertaken by ‘collectives’ and the work becomes far more collaborative with an unguarded attitude to the sharing of results. Knorr Cetina claims that nearly the

opposite is true for molecular biology teams. Chapter 6 noted the significant role of the individual, and this is confirmed by Knorr Cetina's study.

Given such a significant difference in the cultures between two branches of science, it is not inconceivable to differentiate further noting perhaps more subtle though distinct communities within the life sciences.

"For example the yeast community is unbelievably open so there the collaboration is great. But in the plant society it's a little bit more restricted" (Interview: Hungarian Scientist previously of HAS, now in the US, September 2006)

Cultural variation in science is even found in different geographical regions where the discipline is the same, but clearly history and context have a large influence:

"American labs are very good in a lot of things, but I think they might not spend enough time designing experiments. They often like the trial and error approach, they jump on experiments, if it works, great, if it doesn't, let's try another thing. Personally I think that type of approach is a good one but I don't favour it. I favour the research where you put an incredible amount of your energy into designing the experiments...and this skill is extremely useful for me in the United States. This type of training...it was not really training, more like necessity. We could only order chemicals, enzymes from the West once a year. In that time, it was in the communist time...so we learnt that we don't make mistakes... and again it was a necessity for us because the government dictated this way for us. But what they didn't teach me, what they couldn't teach me, is how to do first class research. What I mean by first

class research, is pioneering, that kind of discovery...I didn't learnt that here in Hungary because we were not that developed. To be in the forefront of science you have to be in a laboratory that is in the forefront of science, but we were notably behind, so we played a catch up game. Probably they are still playing that game."

(Interview: Hungarian Scientist previously of HAS, now in the US, September 2006)

The above quote is immensely revealing. It firstly reveals differences between Hungarian and US laboratory cultures in either the careful design or 'trial and error' approaches used which are a result of the history of both countries, the influence of communism and the way resources were organised under that regime. Secondly, it alludes to a component innovative capability: the ability to do 'first-class' or 'pioneering research', which is part of the culture belonging to a lab.

7.4.2. Learning in Epistemic Communities

To additionally characterise the life science communities and add to the understanding of the situated learning concept, we can note from Knorr Cetina's work her observation on protocols (the written procedure of an experiment) "These protocols which have been tried and mastered become part of the laboratories capital. They are sought after, obtained as favour from other labs and taken along by scientists who change laboratories".

However, not all the skills required to be successful in the life sciences laboratory can be learned from simply possessing a protocol. There may indeed be a 'disembodiment' of science with the use of instruments that outperform the scientists own sensory organs. But

despite this, Knorr Cetina argues that the scientist uses their sensory organs in a 'holistic sense', vision for example being particularly important. Thus experimental lab work continues to be skilled manual labour.

The author's own modest experience in a plant biotechnology laboratory and the resulting disaster that inevitably followed testifies to the fact that careful instruction and the continuous practice of good technique is a tacit skill that is learned by practicing biologists quite aside from the following of protocol. Published protocols can rarely keep pace with new equipment, new trends in plant materials etc. An informal conversation with a student who was gradually mastering a specialised piece of equipment and was fast becoming a known expert in the laboratory she worked in, admitted that on occasion when she needed advice on working with particularly difficult samples, she would contact former university graduate friends who were now situated in similar laboratories in other parts of the country.

Even with its claims to be a rigorously documented discipline, we find that there is an art to science and the learning of the tacit skills required to master this art can only be achieved from the situated learning in the laboratory setting. It is possible to speculate here and suggest this as being one of the reasons for the time-resistant perpetuation of reputation observed in Hungary.

Given that this particular community of practice possesses its own culture, what might be the ramifications? The greatest difficulty is dealing with change. Bross et al (1998) talks about the increasing interdisciplinarity of science, with biology for example combining with information technology to create the new discipline bio-informatics. This is indicative of some of the changes which are occurring in the modern scientific world. Within the more

narrow field of molecular biology, Knorr Cetina points to the increasing use of representational technologies and 'signs', where at the molecular level, analysis is done via the interpretation of output delivered by processing machines. Data from this project too shows a dependency on the tools developed by molecular biology. Gel electrophoresis and gas chromatography mass spectrometry are both examples of just two techniques which use specialised machines essential to any plant biotechnology lab. Both produce visual outputs which must be interpreted by the scientist. I observed that many of these machines are now linked to computers with specialised software packages that produce graphical on-screen output. There is a higher level of automation but a yet more differentiated skill is required to learn how to manipulate the software and interpret the output (research observation notes).

Knorr Cetina regards the molecular biologist as something of a black box. There is a great deal of tacit knowledge required in order to translate research results. She describes the separation of action from translation as impossible:

"Results not seen directly or not produced through embodied action cannot be properly evaluated and are prone to misinterpretation." (Knorr Cetina, 2003 p98)

"What needs to be stressed with regard to molecular biology is that scientists act like ensembles of sense and memory organs and manipulation routines onto which intelligence has been inscribed." (Knorr Cetina, 2003 p99)

This was certainly true during Soviet times. The economic savings through division of labour was one of the tenets of the Soviet system, extending through into science. Though the most elegant of theoretical solutions proved not to be as effective as assumed, and this is illustrated by the following quote:

“so they think that if they centralise the institutes then some huge instruments can be used by several institutes. But to tell the truth, this is the second time that it happened in Hungary and the first time, that time we were told the university will be the centre. And they bought the instruments for the universities and in the universities there were some technicians and they always find some problems with the instruments, it doesn't work for that purpose and so on, finally the instrument became too old. So this is an elegant and nice solution to have a centralised use, but I think that not professional technicians should use, however the scientists who are interested in this problem, to solve this problem they should go there and work together with the technicians.”

(Hungarian scientist, September 2006)

The point of this section was to further characterise learning and culture in plant biotech laboratories. There is the development of protocols and the more tacit learning of a skilled manual labour. However, there can be difficulty in dealing with change. In the case of agri-biotech this happens to be the combining with information technology and the increasing use of representational technology. If scientists are regarded as a black box with much learning occurring tacitly, when such changes occur in the technologies used, situated learning as described by Lave and Wenger (1991), is shown to be very important in the

transmission of knowledge and survival of the community. Further problems in coping with the current trends and changes in Hungarian agri-biotech are presented in the next section.

7.4.3. Coping with Trends and Changes in Science

However, current data from this project, and from observation in the largest and most well equipped research centre show a new trend and change in the culture. The progress of complimentary technologies such as IT, and the complexity of new equipment requires a certain mastery which falls to individuals (often PhD students and younger post-docs) who become 'experts' within the lab and are regarded by project leaders as service providers in a way (level 1 concepts: 28, 31, various interviews and observations). The routines required to perform an analysis, although complex, become standardised and differentiated as a separate practice. And this seems to be effective where witnessed. The ABC actually goes a step further and has a smaller unit which serves a number of departments and performs routine sample analysis by a few highly skilled technicians. Green Control BT³⁵ actually out-sources all of its experimentation to the Zoltan Bayer foundation in Szeged and simply analyses the results as an office based activity.

There appears to be a contradiction here given the previously discussed importance of tacit knowledge and laboratory based learning. This is a new trend and this type of activity became apparent towards the end of the fieldwork. While it was the only company to be doing this, the fact that the Bay Zoltan Foundation provides this service to companies, suggests that this is not the only biotechnology company in Hungary to be doing this. To

³⁵ A small bio-remediation start-up company comprising four people hoping to sell bioremediation technology upon completion of their project in November 2007

talk further about the implications of this would require an in-depth case study of this company which is beyond the scope of the present PhD. It may be that the company (which is a small group of experts) knows thoroughly how the mechanics of the work is done and is specialised to such an extent that they require only the results in order to progress the work. While interviewing the director of the company, this appeared to be the case. He, alongside others in the firm had previously developed the technology whilst working in the lab. The project is very close to completion and they hope to soon sell the technology. It may be that outsourcing is appropriate at this stage of the project.

It is not only process innovations and procedures that are benefiting from the shift towards molecular biology techniques and the associated change in culture to one of interpretation. Product innovation too shows some resulting benefit and the change in direction has offered a possibility in a change of output. The ABC in Godollo for example has increased its portfolio of services provided to include the development of molecular markers in demand by classical breeders (see chapter previously).

These developments in the plant biotechnology field require that learning keeps pace. This can be challenging for established scientists. Molecular biology is relatively new and the developments in the field are becoming central to plant biotechnology. At the same time, the generational divide is showing some interesting effects. Younger scientists take on board the learning of molecular biology as an intrinsic part of their field. However, some skills are noted as gradually being lost (level 1 concept: 28). This quote illustrates the generation divide:

G: *“Most young people are very much interested in molecular biology and actually they don’t want to make other things. So they only want to make molecular biology experiments. And it is more difficult to older generations who don’t have much experience in that.”*

B: *“Yes, so this is the other side...that especially the young people, they don’t know the plant, they don’t know the disease, but they know exactly what primer they have to use to – the fancy methods and so on.”*

G: *“They recognise the particular gene for ... but they cannot recognise this in the field”.* (Interview: two Hungarian scientists, September 2006)

Knorr Cetina uses the example of the progress of medical sciences and the change from bedside practice to clinical practice with its corresponding change in the increased power of doctors as experts not having to compete with each other, the no longer dominant role of the patient, the change in language to Latin etc. This describes a re-aligning of the doctor to a new social order and a change in the epistemic culture. In the same way, within the laboratories of agriculture biotechnology scientists, there is a similar re-configuration of social orders being negotiated. This means the altering of institutional relationships which accompany the use of new technologies and a move to the molecular as described previously. This includes the creation of experts as service providers in labs, separate units for differentiated specialized routines and a requirement for continual learning of new methods, protocols and therefore a need to enhance networking, communication and travel.

But in addition, the nature of the technology and its perceived possibility to alter the natural environment when GMOs are transferred to field conditions, means that the work of

scientists is brought to the attention of various other actors and interest groups. E.g. Politicians, the media, NGOs, the agricultural farming community etc. In other words scientists as innovators must participate in a new arena. Cultural practices must change, a new language must be learned in order to communicate with these other actors and new channels of communication must be opened. This is ever more the case as we see the object of study – plants, take on an entirely new function. In the push for the development of solutions to environmental problems, for example in bioremediation, plants become reconfigured as tools, the problem focus shifts as does the context, the customer and in short, the whole set of environmental factors surrounding the scientist and his laboratory.

There is also a new demand from government for science to become less fundamental and more applied. Projects have a reduced life span as science takes on a ‘project culture’. Knorr Cetina writing not specifically what is here termed project culture, nevertheless captures the same dynamic: “Experiments come in generations, but participants think beyond them. The communitarian ontology involves a temporal orientation towards the lifetime of an experiment and simultaneously towards future generations, especially the one succeeding a currently planned, constructed or running experiment. The notion of genealogical time can perhaps capture this double orientation. Participants not only think beyond the lifetime of their current experiment, they also organise activities that point beyond it and involve themselves in these activities” (p.187). Laboratory leaders thus become project leaders and have to acquire skills such as proposal writing, budget creation and they must disseminate information. (level 1 concepts: 12, 13, 20, 22).

In addition there is the demand placed on the scientific community by critics and government actors to develop solutions to actual problems, to produce products or patents. This would require business, market and product knowledge which is on the whole, an alien concept to many of the Hungarian scientists interviewed (level 1 concepts: 12, 13, 20, 22). This is exemplified by the following quote:

“I can make myself understood with my students. But not always when I have to sit down with businessman because their way of thinking is very unfamiliar to me and that kind of expertise ... I don’t think a university educator, or very few of us would become good business men” (Senior molecular biologist, 2007)

While acknowledging that this is a trend and demand made by policy, scientists are unsure how to gain the required skills, entrepreneurship and the entrepreneurial culture apparent in other western countries. Government policy has been either to force this change in direction by selective funding or to fill the gaps by the setting up of centres such as Biopolisz (level 1 concept: 13, 14, 30).

Alongside these changes are changes in communication technologies – email, the internet etc, which have the power to expand the arena and increase the speed of interaction immeasurably.

7.5. Conclusion to Chapter 7

The Hungarian agricultural biotechnology system has suffered some crippling set backs including firstly the reduction of government spending. This caused the downsizing of certain key government institutions, the chemical industry pesticides sector and a general loss of scientific personnel through brain drain. Linkages between these actors have therefore been lost.

However, these same factors which are potentially damaging have had the unexpected effect of triggering networking and collaboration as a particular coping strategy. In the absence of state funding, research institutes are increasingly dependent on EU and other forms of international funding which require the development of European and international collaborations. Research institutes engage in international collaborative projects which allow the utilisation of Hungarian expertise to develop solutions for agricultural problems faced outside the country, further engaging international partners. These links did exist before accession and even before transition, but this context has meant a reinforcement and development of informal and formal international connections. Being extensively linked in such a way means that certain vital information about global and national trends in agricultural biotechnology are sensed and provisions for adaptation and change can be made. Laboratory heads can think strategically about projects and partners and expertise can be developed along the required lines.

The seemingly increasing embeddedness of the innovation system in the globalised scientific community is partly true but the importance of the 'national' still remains.

Linkages between the national actors (universities, classical breeding institutes, older generation networks) are the roots and hub of the system (a point which contributes to research sub-question 2). Yet the linkages which would make this network a true 'innovation system', are missing. There are missing linkages that the innovation feed-back loop innovation model should contain, but doesn't and the path to commercialisation is highly debilitated.

In answer to research sub-question 1, I can say that despite the missing linkages, there is a system of learning and the perpetuation of scientific expertise is continuing, and in some cases, continuing along new trajectories marked specifically by a new generation and the event of molecularisation. It may be described by Lave and Wengers 'community of practice' which is brought together by common interests such as to make progress in science, to publish and to survive. However, the networks that have been created by this community extend beyond the scope of the traditional meaning of communities of practice since benefits can be asymmetric, its involvement is necessarily multi-disciplinary and can require engagement with transversal technologies.

The heart of this community is brought together in a much more permanent way than simply a network of discrete actors, because there is a sharing of an epistemic culture (Knorr Cetina 2003). The culture underpins the community, networks and learning and has given this community distinct characteristics and behaviours which evolve over time to cope with the changing context. The changing context includes for example; the increasing project culture, the need for continuous learning, and the trend in molecularisation that requires changing techniques, instrumentation, language and projects.

Research sub-question 2 draws attention to certain cultural practices of the past that have become engrained and create difficulties when coping with change, for example in engaging with commercial practices and entrepreneurial activities that lead to commercialisation.

For policy to be effective therefore, it is not sufficient to 'plug the holes' and fill the gaps in the innovation system, hoping to smooth the path to commercialisation. Rather attempts must be made to engage the system as a community and to introduce into its culture such concepts as entrepreneurship and risk taking. These changes are long term and require them to be incorporated into the learning and knowledge perpetuation mechanisms of the community.

Chapter 8: Conclusions

8.1. Chapter Overview

This final chapter first addresses, in section 8.2, the research question and sub-research questions posed in chapter 1. Answers to these questions draw together the information, data and analysis in chapters 3, 5, 6 and 7 to formulate answers to each question. Answers to the sub-questions cumulatively build an answer to the overall research question. Section 8.3. reflects on the various policy implications and lessons which may be learnt from the findings presented in this thesis. Section 8.4. addresses the limitations of the study. Section 8.5. reviews the original contribution of the research to the existing field of knowledge and section 8.6. will discuss how the study may be taken forward, with ideas for extended work.

8.2. Answering the Research Questions

8.2.1. Answering Sub-Question 1

Has the network of actors in the innovative agri-biotech sector evolved in a way that accommodates the particular characteristics of the technology?

Innovation in this field is characterised by its high knowledge intensity. The application of plant biotechnology requires a vast amount of prior knowledge to be accumulated not only in terms of scientific expertise but also in terms of familiarity with highly specialised techniques.

The knowledge and techniques that carry the field forward are often advanced globally by actors outside Hungary. Hungarian scientific networks in agri-biotech have always exceeded national boundaries. For sometime prior to accession Hungarian scientists participated in global networks. Chapter 2 noted that even prior to transition, the science community in Hungary enjoyed greater freedom than many of its Soviet-sphere neighbours. Members of the scientific network, in what may be broadly described as a community of practice, are linked by their common interest in sharing problems, experiences, tools and best practices. The examples which may be drawn from chapter 7 illustrated the extent to which scientists participated in, and even hosted international conferences, visiting researchers, and joint research projects. While its primary concern, in exploiting global collaborations may well be to generate funding, a secondary advantage in such participation, is the improved access to first hand state of the art knowledge, equipment and techniques that innovation requires in this field.

While the community of practice concept explains how the overall goals and aims draw the network together, it does not fully explain the dynamics of learning, knowledge creation and knowledge transmission. To understand the existing body of knowledge and to participate in this network requires a full understanding of the language and practices of a molecular plant biotechnology laboratory, in other words, its epistemic culture. For the learning of techniques, best practices and protocols to be transmitted, a practitioner must be situated in the laboratory. It is the dynamic nature of this network that reflects transmission of learning and epistemic culture in the movement of scientists as visiting researchers, as project coordinators and as teaching staff. This core group of actors that generate knowledge and innovation in the basic science of plant biotechnology is held together by

some formal institutions i.e. collaborations, teaching contracts etc., but by many informal institutions, supported and created by the epistemic culture as described in chapter 7. Using the concept of division of labour as put forward by Etzkowitz and Leydesdorff (2000, chapter 3), the weighting is heavily in favour of this group of actors and the quality of institutional arrangements reflects the close proximity that learning and knowledge transmission requires.

The event of molecularisation, which is now a fundamental aspect of this technology, has also played a part in the shaping of this network. The necessity to learn and update the set of skills required to keep abreast of the new equipment and knowledge in the related field of molecular biology further encourages the movement of actors within the core group. Skills in the use and manipulation of molecular tools and representational technologies mean that the network is extending its outreach. This community of practice is benefiting through the development of complimentary communities such as molecular biology. The relationship may be described as mutually reinforcing.

The institutions described above are being challenged in particular by economic circumstances which are causing a middle generation of young professionals to leave the community for careers outside Hungary. While this sometimes extends networks, it reduces the critical mass of individuals that make up the core competencies of a national network.

Crop agricultural biotechnology in this project was initially perceived to be a technology where innovation would result in a distributable product. As a product-centered innovation, it would be expected that a number of downstream actors would be involved in the

development, distribution and use of the product. The network of actors in Hungary does not reflect these activities. There are various reasons for this. Firstly, since national legislation and public opinion does not support the growing of commercial GM crops, there are no users or developers that exist beyond the stage of field trials. Large multinational companies have also withdrawn support for development within Hungary and limited their connections with public research organisations. Secondly, there is the general problem of a lack of an active private sector due to the economic history of the country. This will be further discussed in the answer to the second sub-question below. With a lack of downstream actors to develop and take forward the technology, it is not just a study of how the configuration of the network reflects the particular characteristics of the technology. This project has found that the network adapts the technology for its own purposes, the main one of course being survival. For example, innovation in this technological field in this context has begun to concentrate on the basic knowledge and process-centered innovation as used in molecular marker development, publication of new knowledge etc. (See chapter 6)

8.2.2. Answering Sub-Question 2

Do linkages between actors in the network demonstrate sustained use of institutional arrangements that characterised the pre-transition NIS?

The most prominent feature of this innovation system is the dominance of the public sector. The Hungarian Academy of Sciences, and government research institutions are central to activity in the agri-biotech field.

Chapter 5 described the structure of institutes within the HAS which were established according to the principles of the linear technological development model, concentrating exclusively on 'basic' or non-applied research. The role of the academy remains a controversial question and has been debated in Hungarian society since the 1960s. Government policy has been to adjust funding and introduce new funding-based programmes with the aim of encouraging more applied research. However, the HAS continues to focus on basic research with many of its leaders arguing that without basic research, applied research and innovation cannot occur and that the HAS should remain a home for basic research. This opinion also surfaced in interviews with those outside the academy. The position of the HAS has so far been defended by its strong lobbying power and politically influential leaders (data presented in chapter 5).

The effect of these characteristics on the innovation system is to reinforce the distinction between basic and applied research. The linear innovation model that dominated the pre-transition era created this distinction through both the physical structures of the regime and the thinking that pervades, preventing a more integrated system of science, industry and innovation. Through the lens of national innovation systems theory it is possible to see that the institutions which existed in the pre-transition era are being maintained through the self-interest of the primary actors involved. There is a path dependency that exists due to the cumulative effect of many years of funding dependency on the state that was the only network organiser for many years (see Radosevic, 1999 in chapter 3). With no alternative organiser emerging from the private sector or otherwise, such institutions remain intact.

Irreversibility or lock-in (examined in chapter 3) which also maintains these institutions, the physical research structures and their role in the system, stems from cumulative learning and behavioural patterns that have evolved over many years. In other words, a culture generated in the first instance by the 'scientific socialism' of the Soviet era. An alternative, more entrepreneurial culture (see chapter 7) geared towards applied science and research requires new patterns of learning and thinking that will take time to establish and create the cumulative effect that will eventually lead to a change in trajectory and restructuring of the system.

More may be said upon reflection of the insights on triple helix dynamics put forward by Lengyel and Leydesdorff in 2007 and presented in chapter 3. When looking at the division of labour and quality of the institutions that hold primary actors together, what this thesis has found is a strong core group of actors in the centre of the science system (chapter 5). These actors are undertaking the higher proportion of activity (even if it is centered around basic rather than applied science). Institutions are mostly informal, though increase in formality as networks extend into international collaborative efforts (chapter 7). The role of certain individuals at the management level of public research organisations has much to do with the maintenance of the informal institutions amongst this core group. Institutions either of the formal or informal kind are much weaker between heterogeneous types of actor which make up the remainder of the innovation system. For example between the public and private research institutions or between government and industry groups.

In consideration of the science system, its preserved distinction between basic and applied science and its core competencies that reside with the primary group of scientists, this

thesis can claim an agreement with Radosevic (1999, chapter 3) in the statement that legacies are indeed both a resource as well as a constraint.

Two further legacies, which mostly negatively effect the innovation system, should also be reviewed here: those which concern the basic education system and the private sector.

Chapter 5 demonstrated the main problems of the inherited higher education system. One is the large number of universities and colleges which means that resources in key areas such as science are not concentrated. This leads to the closure of many university biotechnology departments in an unplanned, un-strategic manner. And second, the lack of teaching staff due to universities being mere teaching factories with the best researchers being absorbed into the HAS during the Soviet era. As a result of these problems, universities have difficulties in developing the research culture that would be called upon by the Humboltian model if such a policy were to be advised by government, which looks increasingly likely as Hungary moves into line with the EU agenda as specified by the previously described EC communication of 2003 (see chapter 3). Teaching still remains quite apart from research, though inroads are beginning to be made with HAS and government lab research staff starting to teach courses at universities and PhD students beginning to make use of placements in HAS and other public research laboratories. Occasionally these efforts are frustrated by the reluctance of universities to relinquish the bench fees that accompany research students.

Chapter 5 also highlighted the lack of activity by, or significant presence, of the private sector. While it is recognised that transition and the economic crisis severely hampered the

growth and progress of the private sector, what is more important here is that the pre-transition era was marked by the non-existence of a significant private sector. Industry during central planning supplied an internal market with a guaranteed demand. They also were the recipients of innovations delivered by government research institutes. In the post transition era businesses and public research organisations needed to develop an entrepreneurial culture and the skills and competencies to receive market signals and respond to market demand. The institutional arrangements that would allow a private sector to function have been implemented relatively recently. For example there is a lack of technology transfer offices, law firms, accountancy services and so on. And lastly there still exists the problem of a lack of stable cohesive policy that acts as a complete framework for the interdisciplinary area that agri-biotech innovation would operate within.

8.2.3. Answering Sub-Question 3

Does this existing network, as it has evolved, show difficulty in adapting to the regulatory environment in the country's post accession phase?

Chapter 2 described the EU's regulatory framework that governs the production of GM, Hungary's current position on that framework, and the uncertain political climate surrounding the GM issue. The ban on commercialisation in Hungary presents an immediate problem for the innovation system. Drawing from the features emphasised in the answers to sub questions 1 and 2, we can form an answer to the 3rd subquestion.

This sector of the innovation system as described above is centered around its core competencies and actors in basic science. There is a lack of downstream and private sector actors that would be more perceptive to the needs and demands of the market and so there is a lack of feedback information in the system. This is one difficulty in adaptation.

Another challenge facing adaptive ability is the path dependency and certain types of lock-in that effect these core actors who find it difficult to extend beyond basic science. Applied science and entrepreneurial skills have become difficult to acquire. This stems from cumulative learning and behavioural patterns that have evolved over many years, reinforced by the physical infrastructure of the science and university system.

These cultural practices are reinforced also by the lack of a more sympathetic innovation policy. Government seeks to change behaviour solely through the use of funding instruments and by 'plugging the holes' in the innovation system, hoping to smooth the path to commercialisation without engaging the community as a system and introducing into its culture such concepts as entrepreneurship and risk taking. To 'plug the holes' describes the government approach to improving path to commercialisation. Policies target specific problems. For example, the lack of applied science led to the government to create institutions such as the ABC to provide applied science. To engage the community as a system is an alternative approach which would see policy address the underlying problems in the system, for example, the lack of entrepreneurial and risk taking culture in the science system. These are long term changes requiring these concepts to be incorporated into the learning and knowledge perpetuation mechanisms of the community (Chapter 7).

Change and adaptation to the new environment is further frustrated by a lack of certain actors. There is no network organiser to fill the gap left by the retraction of the state in the post transition era. There is also a growing generation gap between the older established scientists and those who are newly qualified who leave the country for careers abroad, thus leaving no middle generation for teaching and perpetuation of knowledge. And there are few boundary actors, spinoffs and those varied heterogeneous organisations that add to business and other complimentary activities such as in marketing, law, venture capital, and so on.

However, despite this disjointed system which is clearly deficient in the adaptation mechanisms which are seen in more complete conventional innovation systems, this sector has features which show broadly two distinctly different mechanisms for the adaptation and survival of its core competencies.

One of these mechanisms is the outreach of its networks both globally and to complementary communities outside the immediate field. By linking to individuals and research institutes outside Hungary, national actors are able to continue research and publishing activities, channel information about markets and demand for research outside Hungary and are able to gain funding from alternative sources. By linking to actors in complementary communities, alternative skills may be utilised to further adapt the technology (chapter 6).

The second mechanism as briefly mentioned in the answer to sub-question 1, is the adaptation of the technology and change in direction by the actors for their own survival.

As time goes on and the uncertainty in the political environment continues, actors begin to find alternative uses for their skills, for example in the development of ‘soft gene technology’, in molecular marker development, in biosafety etc. There is also the trend of moving back towards the basic science, of using GM technology to study mechanisms that occur naturally and to publish the findings of this basic research (See chapter 6).

8.2.4. Answers to the Overall Research Question

How do context specific institutional factors effect innovative capabilities?

The answer to the thesis’ overall question follows from the answers to the three sub questions above.

This thesis has shown that the political and economic context matters immensely. The use of concepts taken from national innovation systems and triple helix theory demonstrated that the institutions between actors and organisations reflect this historical context. Division of labour has created an innovative sector weighted towards basic science, with powerful basic science institutions and weakened product development. Path dependency and lock-in perpetuates the distinction between basic and applied science, preserving both the physical infrastructure and the thinking that pervades it. The context also involves the regulation and politics which surround the technology preventing the commercialisation of the technology in Hungary.

Innovative capabilities currently reside in the core competencies of the science community in this sector and the networks they have created over time within and outside the country. The nature of the technology itself has shaped the institutional framework that exists between actors and the core competencies of the actors and organisations. The event of molecularisation, continuous lab-based learning, collaboration and communication has reinforced this community through the sharing of an epistemic culture.

The ability to adapt and maintain innovative capability is central to answering the research question on how institutional factors effect these capabilities. Organisations in the network are adapting their activities to survive the current economic hardship and political uncertainty that they face. Adaptation strategies exploit the competencies and features that are characteristic to this sector, the actors and institutions. Such strategies include for example, global and national collaborative efforts, basic science research and publishing, and the development of non-GM complimentary technologies. The employment of innovative capabilities in these activities, will for the time being preserve them. As adaptation occurs with new activities being developed under the pressure of the context on its institutions, organisations begin to demonstrate new trajectories.

Institutions hold both the adaptive mechanisms for change and the legacies of the past which can help or hinder that change. The ability to adapt and survive is being challenged by a number of factors such as the limitations of a non cohesive policy and regulatory framework. This leads to a lack of key actors such as boundary actors, private sector actors and network organisers. There is also a lack of feedback in the system due to the lack of a market and downstream actors. And finally the system is being challenged by the economic

difficulties that results in the closure of facilities and the loss of a middle generation of qualified graduates.

8.3. Policy Implications and Lessons

This study has shown a number of important factors that must be considered carefully in any discussion on policy within and also outside Hungary. These are discussed in points a-g below:

a) The importance of the political and economic history in the formation and features of the innovation system. Here certain legacies of the past may be carried forward in a way that prevents the innovation system reacting as expected to a policy initiative or tool. For example, in Hungary the main policy tool that the government intended to use to shape the innovation system is altering the conditions of funding so that only projects with an applied aspect would achieve national support. While this has to a certain degree been effective, there are no supporting policies that demonstrate an understanding of the science system and no debate or discussion on how to break path dependency, the cumulative effects of learning and the reinforcement of the scientific culture that perpetuates concentration in the basic sciences.

b) The competing influence of different policy levels in any single field which in this field means the competing influence of overall science and technology policy which aimed to promote development and regulatory policy which bans all GM commercialisation. This indicates that a certain amount of policy cohesion is required for an innovation system to

function effectively. In a multi disciplinary area such as biotechnology where science and technology policy is controlled by one ministry and the competent authority for GM regulation is controlled by another, cross communication and co-ordination may be difficult, but is absolutely vital. If it is not achieved, such competing policies will shape the innovation system, for better or worse, as has occurred in Hungary.

c) The significance of funding, its source and how it influences activity. The funding source is tied inextricably to the aims and goals of the research. Where national funding is the main source of funding, national priorities will become the priorities of the sector. Where European or international funding sources are made available alternative agenda's can become the goal of actors and organisations. Agenda's and funding will eventually effect the day to day activities of the actors – everything from spending time in writing proposals to organising international conferences in order to meet potential project or funding partners. The dependability, availability and transparency of these funding sources also have an impact on whether they become the main source for the actors involved.

d) Political uncertainty and how it effects the activities and strategic planning of actors. The lack of a clear signal in Hungary as to what the government requires from the research sector has meant a diverging of activities in various directions. In this case, activities on the whole have shown a beneficial preservation of innovative capability. But just as easily in less fortunate circumstances, activities might lead to a degeneration of these capabilities. For example if research activities were denigrated to merely being services for other sectors or other countries or by loss of research capabilities through experts leaving the country or switching sectors.

e) The need for a market for innovation. The linear technology push model is no longer the only model which must be considered in the formation of an innovation policy. For an innovative sector to take off and to develop, it needs an outlet for its creative abilities. Market demand promotes sustainability in the research sector and offers a direction for researchers which can act as a co-ordinating force that creates levels of activity, system integration at the process and product level and pulls the innovation system together with aims and goals.

f) The importance of networks, communities and culture for the science system. Policy must allow for innovative actors to build connections and networks both nationally and internationally, between different sectors and between public and private actors. This is important for knowledge sharing and creation, for learning, for the channeling of market relevant information and so on. Policies that facilitate the building of connections between actors such as promoting the travel of scientists, cross disciplinary university programs, networking events, cross teaching programs etc. would be particularly beneficial.

g) The crucial point of developing an entrepreneurial culture. Government policy has been to directly plug the gaps in the system in order to compensate for the absence of certain actors. While this has to an extent been effective and beneficial, it is not sufficient. For the system to flourish in the long term, an entrepreneurial culture must be fostered within the science and innovation system. This can begin as early as during university education for young researchers. In the formation of such a policy, the system must be considered not only as a network of skilled individuals but as a community with a culture. Concepts such

as risk taking and entrepreneurship must be introduced gradually and at various levels so that they become an integral part of that culture.

8.4. Limitations of the Study

This study viewed innovative capabilities from a more social than technical perspective. From the operationalising of the research questions using theoretical literature that used the institutions, routines, behaviours and habits of the actors involved, the study may have missed certain process or product innovations that were purely technical with undetectable reorganisation or accommodation of such progress in the human institutions surrounding it. To detect and study purely technical innovations requires an up to date technical knowledge of plant biotechnology and its progress worldwide. This is a knowledge not possessed by the author.

A relatively small proportion of the data related to the policy making field. Since the science community was easier to reach and more communicative, the study reflects the greater depth of understanding gained by looking at thinking and progress in the science laboratories of Hungary. This study draws the conclusion that policy does not consider certain factors as listed above and while the all evidence points to this fact, the thinking and abilities of the policy makers themselves were not assessed. And so this study remains blind as to whether policy makers are unaware of the dynamics of the innovative science community or aware of the situation and have not the tools to create and implement alternative policies. The data which justified the conclusions tried to make up for the lack

of policy makers by interviewing academics who are knowledgeable on Hungarian policy and other government actors who indirectly contribute to policy making.

The study also lacked interviews with small enterprises dealing with plant biotechnology since these were impossible to find. It is assumed that very few exist due to the nature of the market and the impossibility of commercialising any GM product within the country. The study did, however, make use of interviews with a small enterprise who dealt with bacterial bioremediation in order to find out what are the factors which most effect small enterprises in the wider field of biotechnology.

It is useful here to review the degree to which the study has been successful in terms of generalisability. Chapter 4 discussed that the claim to generalisability lies in the examination of the various factors which combine and contribute to Hungary's uniqueness, as is the case for all countries. For example, many countries face economic crises, economic transition, regulation that prevents innovation, and so the study looks at how the science system and the innovation system responds and how its institutions adapt to such changes. These are the universal concepts where generalisability allows lessons to be drawn. However, generalisability can always be questioned where there is a single case under examination.

8.5. Original Contribution

This thesis offers three main insights;

First, the context of a country in transition has allowed me to investigate in depth innovation from a different and particular angle. The present research studied the institutions that effect innovation and also allowed investigation of what happens to innovative capabilities when these institutions were radically changed or greatly stressed. Regarding this point, the research results point to the importance of a clear, enabling regulatory framework, coordinated science and technology policy, political stability and the gaps that policy must consider when radical change takes place in order that expertise in both upstream and downstream areas exist and knowledge and information flows between them.

Secondly, the thesis uniquely explores how an innovation system in the context of transition has come to rely on a science system as its most durable part and how this core part of an innovation system has conserved its innovative capability when all else around it disintegrates. Actors, organisations and the institutions which link the core science system, have shown remarkable capacity for adaptation. However, the thesis has also shown that institutions are key to survival of capabilities and their ability to adapt.

And finally, there are lessons in this thesis drawn from Hungary relevant to transition. The thesis suggests that the science system in relation to the overall innovation system has not been well integrated. The structural divisions between basic and applied science are important and policies have not been developed to link them or build more entrepreneurial cultures of application. Changes of cultures and institutions are required in a new economic regime. The more powerful institutions of science have allowed science systems to become more open and entrepreneurial, but less so the other parts of the innovation system. To this

the rigidity of the regulatory system has played its part in weakening application cultures. Institutions in innovation systems hold both the adaptive mechanisms for change and the legacies of the past which can help or hinder that change.

8.6. The Next Step

In any PhD thesis, resources limit what may be achieved. A study as detailed as this offers some crucial insights but even more may be gained by an extension of the work. Ideally this would have included a comparative study with another country with similar capabilities, similar institutions and also having recently undergone transition. Countries that fit this description include the Czech Republic and perhaps Poland.

Alternatively, the agri-biotech sector might be usefully compared with a sector whose regulatory framework does not abruptly limit the possibilities and market for innovation. A good comparison would be human health technologies which are beginning to show many signs of activity in Hungary.

However, this is a study where the current context and time matters a great deal. The most natural and obvious extension of the project then would be to visit the same institutions and speak to the same core group of scientists in 5 or perhaps 10 years. The political situation is bound to change and reduce in uncertainty regarding the legalization of GM crops and it would be interesting to continue to study adaptive mechanisms and innovative capabilities as this time approaches.

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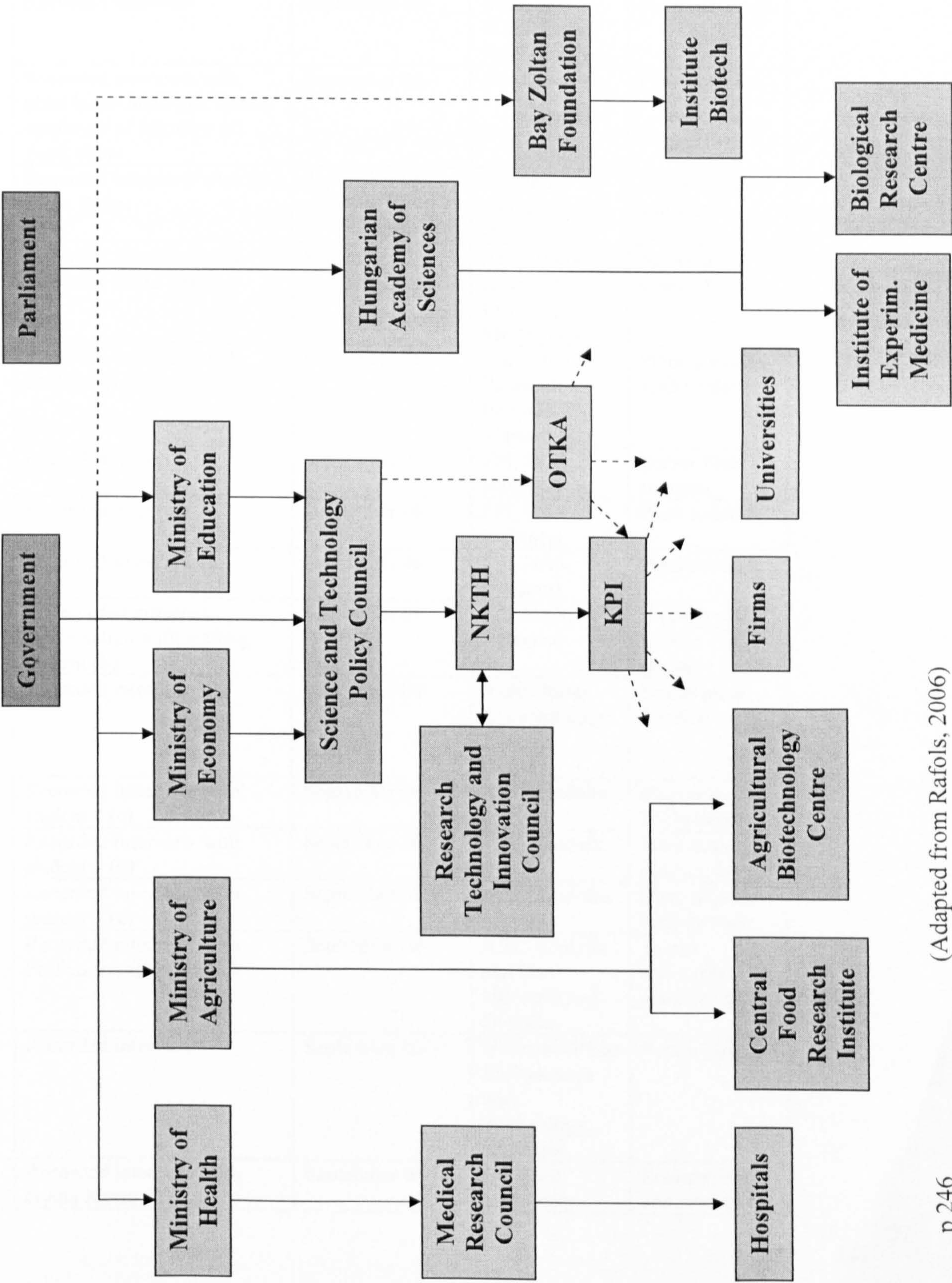
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Appendix A: Hungary's Main Policy Making Institutions



(Adapted from Rafols, 2006)

Appendix B: List of Interviews

Event	Date	Location	Interviewee category
Recorded interview with Hungarian senior scientist based in the US	September 06	Budapest	Plant scientist
Recorded interview	September 06	Instit. for World Econ. HAS Budapest.	Social scientist
Recorded interview with plant biotechnologist former employee of Ministry of Agriculture	September 06	Budapest	Plant scientist
Recorded interview with Dr Janos Balint	September 06	Corvinus University, Budapest	Social scientist and plant scientist
Recorded interview with Professor Ervin Balazs	September 06	Agricultural Research Institute, Martonvasar	Senior plant scientist
Recorded interview with student (a)	September 06	Agricultural Research Institute, Martonvasar	Plant science PhD student
Recorded interview	September 06	PPI, HAS, Budapest	Senior Plant scientist
Recorded interview	September 06	PPI, HAS, Budapest	Plant scientist
Recorded interview	September 06	PPI, HAS, Budapest	Plant scientist
Unrecorded informal conversation with visiting student (b)	September 06	PPI, HAS, Budapest	Visiting plant science PhD student
Recorded interview	September 06	Agricultural Biotechnology Centre, Godollo.	Senior plant scientist
Recorded interview with student 1 (c)	September 06	ABC, Godollo.	Plant science PhD student
Recorded interview with student 1 (d)	September 06	ABC, Godollo.	Plant science PhD student
Recorded interview with student 1 (e)	September 06	ABC, Godollo.	Plant science PhD student
Recorded interview with Professor Laszlo Hornok	September 06	ABC, Godollo and the University of Godollo.	Senior Hungarian plant scientist
Recorded interview	September 06	National Office for Research and Technology, Budapest	Policy official
Recorded interview with Gyula Kasza	September 06	Corvinus University,	Social scientist and advisor to

		Budapest	the ministry of agriculture
Unrecorded interview	September 06	Budapest	Social scientist
Recorded interview	September 06	Monsanto Office, Budapest	Plant scientist
Recorded interview with Prof Kirlay	September 06	PPI, HAS, Budapest	Senior plant scientist
Recorded interview	September 06	Head of Agriculture Policy Research Dept, AKI	Social scientist
Unrecorded interview	October 06	Syngenta Office, Budapest	Company representative
Recorded interview	October 06	Budapest University of Technology and Economics	Senior social scientist
Recorded interview	October 06	Budapest University of Technology and Economics	Social scientist
Recorded interview with Professor Anna-Marie Inzelt	October 06	IKU Innovation Research Centre, Corvinus University, Budapest	Senior social scientist
Recorded interview	April 07	Szeged	Senior molecular biologist
Recorded interview with Istvan Molnar director of Biopololiz	April 07	Biopololizs, Szeged	Lawyer and CEO
Recorded interview with Dr Istvan Vesselenyi	April 07	Budapest	Director of a small Hungarian biotechnology spin off firm and molecular biologist
Unrecorded informal conversation with senior university administrator	October 06	Budapest	Senior university administrator

Names have been removed where necessary or requested to ensure anonymity

Appendix C: List of level 0 and level 1 concepts

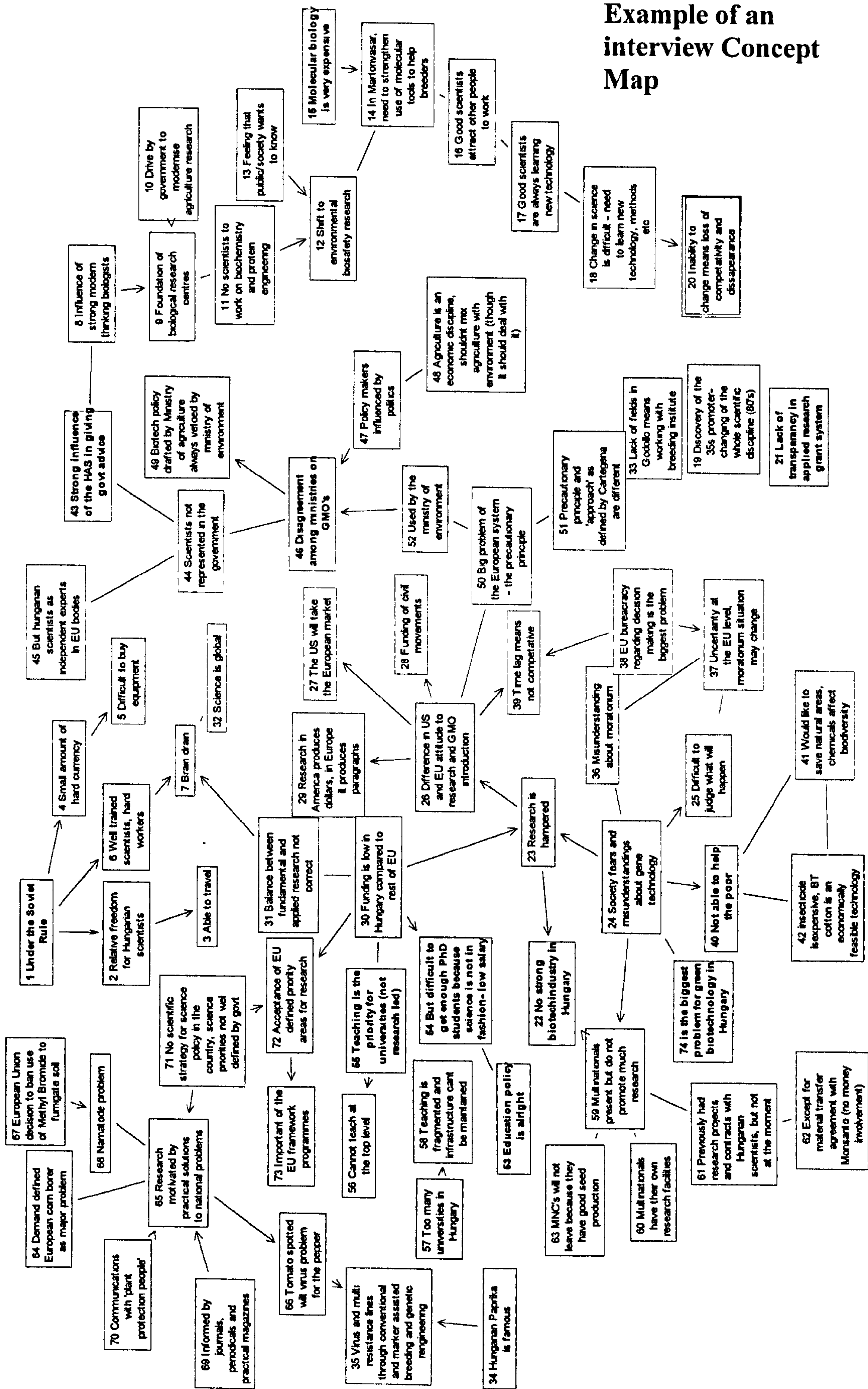
Level 1 concepts and their definition are given in the central column. These are tabulated against level 0 concepts. Letters in the last column represent interviews and are alongside the level 0 concepts drawn from each interview.

Concept Priority	Concept and description	Cognitive map links with ground level concepts
18 C	Brain Drain People leaving the country on a permanent basis linked to opportunities abroad, funding and uncertainty in their home country	N: 1, 2, 4, 5, 7, 15, 41, 43 Bl 7,32 Bf 22,23,25,26 H 12 Br 57,58,59
3 D	Uncertainty Uncertainty in EU policy, uncertainty in securing employment within the field of biotech	Bl 25,37, H 40
8 D	Skills Gap Grounded concepts related to the negative gap between skills in the biotech sector in Hungary and skills elsewhere in the world. Concept may be related to brain drain, competitiveness	N 2 Bl 11,14,18,17 Bf 46,47 Br 78
6 D	Research Lag Reference to grounded concepts which directly identify a lower quality of research undertaken in Hungary and the rest of the world	N 3, 13 Bl 23 H 48 Br 56 S 60
15 C	Quality of Hungarian Research Positive characteristics of Hungarian research and staff with possible historical links to socialist era training in comparison to other areas of the world.	N 9, 10, 11-(12) Bl 1,2,3,6,8 Bf 42 H 48 Br 49,71 S 40,47
7 D	Past Supply Problems Problems in the soviet past leading to a past and therefore inherited lack of equipment, under investment which might also affect the nature of science and scientists today	N 12-(11) Bl 4,5 H 1,2 S 61
12 C	Current Equipment supply problems Grounded concepts indicating the lack of equipment, its causes and consequences.	N 14 Bl 15 Bf 53,50 H 22 S 56,57,58,62,63,64,65
8 D	National level collaboration Collaborative efforts taking place between Hungarian institutes, universities and industries.	Bl 33 Bf 7,16 Br 68,52,67,65 S 59
20 C	European Collaboration References specifically to European collaboration, the reasons for and results of. The difference between collaboration patterns in Europe and the rest of the world.	N 16, 18, 19, 20, 21, 22 Bf 8,29,30,51,52 Br 68,52,65 S 4,69,23,59, 70, 71
14 C	International collaboration	Bf 31,33,34,51,52 Br 68,52,65

		S 7,8,59,4,5,6
42 A	Network evolution Communities of practice, difference between Hungary/Europe and the rest of the world. Interaction which results in contacts made but not necessarily collaborative work outcomes.	N 17 Bl 70,45 Bf 49,46,47 Br 6,7,8,10,13,33,32,63, 54,45,69,71,48,44,47,60,61, 66, 13 S 4,5,6,70,18,20,21 22,48,49,39,38,44,46
9 D	Basic and Applied The path from basic to applied research, views on what constitutes basic and applied research, the difference in gaining funding.	N 23 Bl, 31 Bf 20,21 Br 22,23,24,39,43
34 A	Funding The results of government policy generally in the funding of science and technology	N 36 Bl 5 Bf 26,28,32,37,50 Br 17,25,36, 74,75,76,51,56 S 35,47,2,10,12,13,71,14 15,16,17,32,34
3 D	Path to Production From research to product development, the occurrence of bridging institutions, the link with private industry and MNC's.	N 24 B 35,36
6 D	Applying for funding Concepts related to the bureaucracy of funding applications, transparency, description of funding systems in the EU and in Hungary	N 25, 26, 27, 28 Bl 21 Bf 48
6 D	Output The nature of output, papers, patents, reasons for.	N 29 Bl 29 Br 72,73 S 1,9
10 C	Basic Education Inherited systems of education from school up to and including university and contributions made to current science	N 30, 31, 34, 35 Bl 53 H 3,4,5,6 Br 71
34 A	Policy and Universities Current government policy concerning universities, trends in university education, internal university policy	Bl 54,53,55,56,57,58 Bf 14,15,18,21,45 H 15,16,17,18,19,20, 44,45,47 21,23,24,25,26,41,42,43,46 Br 7,9,10,11,14,
8 D	Politics of communism on science The direct affects of the communist system on the uptake of scientific ideas. Descriptions of the university – Academy system	N 31, 32, 33 H 7 Br 1,3,4,16
30 A	Biotech Policy & formation processes The involvement of different actors in the policy making process. Indicators of government approach/attitude	N 40, 42 Bl 9,10, 30, 31,28,47,44, 46,48,49,52,71,72 Bf 17,10,19,26,27,34 H 14,27 Br 19,20,21,30,41,43 S 62, 68
10 C	Multilevel Governance EU policy, supranational levels of policy and government	N 39, Bl 67,37,26,38,45,50,51 ,72,73
25	Shifts In Science	Bl 12,18,19,20,67,17

B	Noted transitions or shifts in scientific practices related to opportunities, coping mechanisms etc.	Bf 2,10,11,13,43 Br 21,38,78,77,51,50 S 45,23,31,38,52,53,54,55
10 C	Influence of Publics Close ties to the policy making expected	Bl 13,24,28,36,47,74,26 Bf 10 H 28 S 25
23 B	Links With the Private Sector	Bl 22,59,60,61,62,63 H 30,31,32,33,34,46 Br 27,28,35,34,39,31 S 42,39,41,38,33
3 D	The competitive Market	Bl 27,39,42
7 D	Personal Motivation	Bl 42,40,41 S 26,29,27,28
22 B	Practical direction Direction given to science related to practice and problem solving	Bl 35,64,65,66,68,69 Bf 5,6,12,39,40,41 H 39 S 1,9,11,69,54,32,36,46, 47
8 D	Demographic of scientists	Bf 44 H 13 B 55,78,77 S 44,45
19 C	Economic Background and Crisis	H 9,10,11,13,29,35,36 37,38 Bf 28 Br 5,6,23,29 S 50,51,48,67,66
7 D	Current structure of the research sector	Br 24,23,10,16, 40 S 37
3 D	Use of IT	Br 53,54,55
4 D	Accession changes	Br 44,45,46,47

Appendix D:
Example of an
interview Concept
Map



Appendix E: Phytotron facility at Martonvasar

Picture 1



Picture 2

